Chapter - 6
6.1. INTRODUCTION

Exploration of natural resources, particularly earth’s resources, is vital for socio-economic development of any country. The state-of-the-art technology of space-based observation systems offers timely and accurate information from various land and water resources. It can be noted, through the potentials of orbiting space platforms were first realized at the time of launching the Russian “Spuntnik” the very first satellite in 1972 with the launch of ‘Earth Resources Technology Satellite’ (ERTS). The various applicants and studies carried out in India and elsewhere in the world prove that satellite remote sensing technology is most optimal for monitoring and management of various natural resources. Currently, data obtained from both earth resources satellites and meteorological satellites are being effectively utilized to generate vital information at local, regional, national and global levels.

Management of natural resources calls for periodic inventory of these resources, both in terms of their quantity and quality. Remote sensing from orbiting satellites is now being used as an alternative technology for the inventory, survey, planning and management of natural resources and monitoring of environmental change. This necessitates an information system
for analysis of large amount of spatial data. Conventional methods for data analysis includes the usage of hard copy outputs such as maps and tabular data files. These are not only time consuming but also tedious and quite often error prone (Thomas & Kiefer 1979).

Another major constraints is the different levels of scales used by different organizations and application, which calls for considerable labour to register different layers of information when across theme data integration is needed. This exercise is almost invariable in any natural resource monitoring program. Hence an effort for automation at various stages is necessary to ensure raid spatial data updates and effective utility of the available data.

In 1960, when the term remote sensing was first coined it simply referred to the observation and measurement of an object without touching it (Fisher 1975). Remote sensing is the “science of observation from a distance”. It depends on “the scanning of target by a sensitive device from some distance away from it” (Barret and Curtis 1982). It is the science and art of obtaining the spectral information about an object, area or a phenomenon through the analysis of data acquired by a device that is not in contact with the object, under investigation (Lillisand et al 1979). Remote sensing is now considered to be one of the modern branches of Earth Sciences.

Advancement of remote sensing by using satellite images is now taking more momentum than ever before. Remote sensing techniques provide an
excellent tool for a better understanding of the earth's features including the lineament tectonics and, intern, the occurrence of the groundwater. Distribution of groundwater over the earth's crust is not uniform and is subjected to a wide spatio-temporal variation depending up on the underlying rock formations, their structural fabric and geometry, surface expression etc. Hence, it is prerequisite to understand the surface geology, geomorphology, and structural set up as these factors demarcate the zone of recharge. Image or air-photo interpretation is attempted using a set of photographic and geotechnical elements. The study of the photographic and geotechnical elements like, shape, patterns, tone and textures, which are identified through remote sensing, provide either direct or indirect evidences of many hidden structural. From the interpretation of satellite imagery in conjunction with sufficient ground truth information, it is possible to derive some significant conclusions about the characteristics of hidden structures.

This chapter deals with the application of remote sensing techniques for mapping the geology, structure and understanding their impacts over the hydrological conditions of the study area and the first part has been devoted to the fundamental aspects of remote sensing, including the satellite missions and previous works carried out using the application of remote sensing techniques in geological studies. The second part is confined to the image interpretation as applied it the present work.
6.2. REMOTE SENSING

Remote sensing is the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area of phenomenon under investigation. Remote sensing is concerned with the measurement of force fields, electromagnetic radiation or acoustic energy. The techniques employ devices such as the camera, lasers and radio frequency receivers, radar systems, sonars, gravimeters, magnetometers and syntillation counters. Three important variations, which forms the basis for deriving the information about objects are:

i) **Spectral variations**: The changes in the intensity of radiation with wavelength.

ii) **Spatial variations**: The changes in the intensity of radiation with location.

iii) **Temporal variations**: The changes in radiation with time.

1. Data acquisition

2. Data analysis

Data acquisition is done through sensors mounted on platforms. The data may be pictorial or numerical

The remotely sensed data are available in two forms.

i) Imageries and photographs

ii) Digitized data on tapes.

Data analysis involves examining the data using various viewing and interpretation devices to analyse the data.
FIG. 6.1. EXPANDED DIAGRAM OF THE VISIBLE AND INFRARED REGIONS AND THE MICROWAVE REGION SHOWING ATMOSPHERE WINDOWS. (WAVELENGTH BANDS COMMONLY USED IN REMOTE SENSING SYSTEM ARE INDICATED AFTER SABINS, F.F. 1987)

Electromagnetic spectrum. Expanded versions of the visible, infrared regions, and microwave regions are shown below.

**ULTRAVIOLET**

**VISIBLE**

**INFRARED**

**MICROWAVE**

**RADIO**

**IMAGING SYSTEMS**

- Thermal Color Imagery
- IR Color Imagery
- Aircraft IR Scanners
- Satellite IR Scanners
- L-Mband Scanner
- X-band Radar
- Ka-band Radar
- L-band Radar
i) Study and analysis of transparencies or photographs are done with the aid of visual interpretation technique. In this technique, the identification and study of the objects are carried out considering concurrently all the photo recognition elements such as tone, texture, colour, pattern, shape, size etc.

ii) The analysis of digital data is carried out with the aid of computer-processed techniques.

With the aids of the referenced data the analyst extract information about type, extent, location and condition of the resources over which data were collected. This information is generally presented to the users who apply into their decision making process.

6.2.1 PRINCIPLES AND PRACTICE OF REMOTE SENSING

6.3.1 Basic principles

The sun's radiation energy (Electromagnetic) radiates the earth's objects. Depending upon the characteristics of these objects, various types of interactions are expected like reflectance, transmittance, absorption and reradiation. Radiation effects can be measured or photographed. Each object has a characteristic response with reference to a wavelength or wave band, and is termed as its spectral signatures. The characteristic of wavelength bands commonly used for remote sensing is given in Fig.6.1.
Electromagnetic (EM) energy can be detected in three ways:

1. Photographically using camera
2. Electro-optical using camera
3. Electronically using radar and other devices (Basion).

The electromagnetic spectrum is divided into several bands and ranges.
Not all regions are useful for remote sensing. The wavelength regions used in remote sensing are:

1. Optical wavelength region-Visible 0.4-0.7μm, reflective 0.7-3.0μm
2. Emissive wavelength region 3-16 μm and
3. Radar wavelength region 0.833-133 cm.

The instruments capable of measuring the EM radiation even from a further distance are called as sensors. These sensitive devices are of two types, as:

1. Passive sensors, which do not have their own source of radiation. They are designed to capture the effects of natural radiation. This is mostly obtained from reflected sunlight. Cameras and Photodetectors are suitable examples.
2. Active sensors have a built-in source of radiation. Radars have transmit and receive the waves sent for interaction.
The sensor system of the satellite can be classified into two categories:

1. Imaging sensors which are subdivided into (a) "framing system" (aerial photographic camera, vidicon) and (b) "scanning systems" (MSS, TIRS, Radars).

2. Non-imaging sensors, data systems (Eg. Lidar spetoradiometer, thermal radiometer, passive microwave radiometer, radar scaterometer).

An image is a two dimensional representation (replica) of the spatial signature of an object with respect to its spectral features.

6.3.2 Indian Remote Sensing Satellites

The Indian remote sensing programme had a modest beginning in the early sixties when aerial platforms were used to acquire information about the earth resources. The first Indian experimental satellite, sent by India for earth observations, was Bhaskar-1. This was placed into the orbit by a Cosmos rocket from Russian cosmodrome on June 7th, 1979. Bhaskar had a payload consisting of two band TV camera for land applications and a satellite Microwave Radiometer (SAMIR) for oceanographic / atmospheric applications. However, experimental studies were conducted primarily using LANDSAT data, towards the development of operational methodologies for resource management applications (Table 6.1)
6.3.3 IRS-IA, IRS-IB, IRS-IC AND IRS-1D Satellites

The first indigenous operational remote sensing satellite IRS-IA was launched in March 1988, which continued to provide excellent data even beyond its mission life of three years. The second satellite, IRS-1B, (identical to IRS-1A) was launched in August 1991 with the linear Imaging Self Scanner (LISS)-I and LISS-II on board. These satellites have provided the images in four spectral bands in the visible and near infrared (NIR) regions (0.45 to 0.86 microns) with spatial resolution of 72 meters and 63 meters respectively. The second generation of IRS satellite include IRS-1C and IRS-1D was successfully launched on September 29, 1997. When compared to IRS-1A/1B, sensors of these satellites have a better spectral and spatial resolutions, more frequent revisits, provision for stereo-viewing and on-board recording facility. These satellites have three sensors namely LISS-III, Panchromatic (PAN) and Wide Field Sensors (WiFS). The LISS-III sensor has four spectral bands in the 0.5-0.70 micron region, with a swath of 142 km and a spatial resolution of 23 meters (70 meters for short wave infrared band). The PAN camera with spectral band of 0.50 – 0.75 microns and swath of 70km provide a spatial resolution of around 5.8 meters and has a steering capability up to + 260° which will enable frequent revisits and are suitable for stereo viewing. The WiFS sensors operate in 2 spectral bands viz. red and near infrared, with a spatial resolution of 188 meters and swath of 774 km enable monitoring of vegetation dynamics (Sebastian, 1996). The characteristics of Indian remote
sensing satellites and sensors are given in the Table 6.1. Satellite data products are as follows:

1. False colour composites (obtained by combining all multispectral bands of the same scene.
2. TM. (Thematic maps)
3. Positive and negative films
4. Digital data in CD’s tapes and floppy disks.

False color composite are produced from colour infrared film in which blue coloured objects primarily in green, green objects results in the reflection of red energy, and red objects reflecting primarily in the photographic infrared portion of the spectrum (0.7 –0.9mn).

6.4. VISUAL IMAGE INTERPRETATION

Image interpretation needs systematic and frequent examination of object present in the imageries. Maps and reports of field observation are other importing supporting materials to be used during interpretations. Success in photo interpretation varies with the training and experience of the interpreter, nature of the objects being interpreted and the quality of photographs being utilized.

The satellite data interpretation can often be facilitated through the application of a certain interpretation keys. This will help the interpreter to
evaluate the information presented on imagery in an organized and consistent manner. It provides guidance about the correct identification of features or conditions on the photographic images. The two types of commonly used image interpretation keys, are:

1. Selective keys and
2. Elimination keys

A selective key contains numerous imagery examples with the supporting texts. The interpreter selects the example that most nearly resembles the features found on imagery. An elimination key is an orderly arrangement in which the interpretation proceeds step by step from the general to the specific and leads to the elimination of all other feature or conditions except the one being identified.

Any image interpretation considers the following six basic elements.

Shape – refers to the general form or outline of individual objects, which is of same significance to the photointerpreter.

Size - of object on photograph must be considered in the context of the photographic scale.
### TABLE: 6.1. – CHARACTERISTICS OF INDIAN SATELLITE FOR EARTH OBSERVATION (AFTER KASTHURIRANGAN et al., 1996)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Bhaskar-I &amp; II</th>
<th>IRS-1A/IB</th>
<th>IRS-1C/ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class</td>
<td>Spin stabilized</td>
<td>3-axis stabilized</td>
<td>3-axis stabilized</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>444</td>
<td>975/898</td>
<td>1247</td>
</tr>
<tr>
<td>Power (W)</td>
<td>47 W from solar panels and Ni-Cd batteries</td>
<td>709 W from solar array (EOL) 2 Ni-Cd batteries</td>
<td>813 W from solar array (EOL) 2 Ni-Cd batteries</td>
</tr>
<tr>
<td>Mission of life</td>
<td>One year</td>
<td>Three year</td>
<td>Three year</td>
</tr>
<tr>
<td>Orbit Height (km)</td>
<td>Apogee 557 Perigee 572</td>
<td>904</td>
<td>817</td>
</tr>
<tr>
<td>Inclination (deg)</td>
<td>50.7</td>
<td>99.028</td>
<td>98.12</td>
</tr>
<tr>
<td>Type</td>
<td>Near circular</td>
<td>Sun-synchronous</td>
<td>Sun-Synchronous</td>
</tr>
<tr>
<td>Equator crossing time</td>
<td>10.25°</td>
<td>10.30</td>
<td></td>
</tr>
<tr>
<td>Repetivity (days)</td>
<td>22</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### TABLE: 6.2. – CHARACTERISTICS OF REMOTE SENSORS ON BOARD INDIAN SATELLITE FOR EARTH OBSERVATION (AFTER KASTHURIRANGAN et al., 1996)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Bhaskara I/II TV</th>
<th>Bhaskar I/II SAMIR</th>
<th>IRS-1A/IB LISS-I/II</th>
<th>IRS-1C/1D LISS-II</th>
<th>IRS-1C/1D PAN</th>
<th>IRS/1C/1D WiFS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>TV camera</td>
<td>Dick-type Microwave Radiometer</td>
<td>CCD camera</td>
<td>CCD camera</td>
<td>CCD camera</td>
<td>CCD camera</td>
</tr>
<tr>
<td>Spectral Bands (m)</td>
<td>0.54-0.66</td>
<td>19.21,31 (GHz)</td>
<td>0.45-0.52</td>
<td>0.52-0.59</td>
<td>0.52-0.59</td>
<td>0.5-0.75</td>
</tr>
<tr>
<td>Ground Res. (m)</td>
<td>1km</td>
<td>125km</td>
<td>73/36.5</td>
<td>-23 (VNIR)</td>
<td>5.8</td>
<td>5.8</td>
</tr>
<tr>
<td>Swath (km)</td>
<td>-341</td>
<td>148/2*74</td>
<td>-140</td>
<td>-70</td>
<td>810</td>
<td></td>
</tr>
<tr>
<td>Steering</td>
<td>Nadir</td>
<td>Nadir</td>
<td>Nadir</td>
<td>Steerable + 26°</td>
<td>Nadir looking</td>
<td></td>
</tr>
</tbody>
</table>

67
**Pattern** – relates to the spatial arrangement of objects: The objects and their shadow are important to an interpreter in two respects 1. The shape or outline of a shadow affords a profile of objects (which aids interpretation) and 2. Objects within shadow reflect little and are difficult to discern on photograph, (Which hinders the interpretation).

**Tone** – refers to the colour or the relative brightness of objects on the photographs. Without tonal differences the shapes, pattern and texture of objects could not be discerned.

**Texture:** is the frequency of tonal change on a photographic image, which is an important parameter for image interpretation.

**Site** or location of an object in relation to the other features can be very helpful in identification (Thomas Lillisand et al 1979). Before interpretation the interpreter should have enough background information on meteorology, forest cover, cultural features, topography, geology, pedology, and hydrology. These elements have considerable influence over the colours of the imagery.

### 6.5. REMOTE SENSING APPLICATIONS

Remote sensing data are increasingly being employed to prepare the thematic maps pertaining to the geology to the geology, structure and
lineament, hydrogeomorphological units, land use and land cover and environmental techniques also made a continuous change in the mapping procedure. Presently remote sensing has become an integral part of any mapping programme. The geocoded data available in the form of photographic prints (imagery) acts as a better database for all the field geologists. Pictorial data not only improves the accuracy of observation but also reduces the number of field traverses to the barest minimum, thus reducing the time and cost of the mapping programmes. Geological information like disposition of various lithologic units and structures play an important role in identifying the groundwater potential zone. The aspects of morphography, morphogenesis, morphochronology and morphometry are vital inputs in the preparation of geomorphological maps. Information on existing land use / land cover and pattern of the spatial distribution forms the basis for every development planning. The land use / land cover maps have to be prepared by adopting visual interpretation techniques in conjunction with collateral data such as topomaps and census records.

Satellite image interpretation studies, which provided only the qualitative information earlier, are slowly becoming appropriate for obtaining the quantitative data of objects. It can help in assessing the environmental system studies like rural and urban dwelling densities, industrial pollution surface water pollution, oil leakage, deforestation, soil erosion, forest fire, flooding, land slides, air pollution, dispersion and circulation, movement of
suspended sediments, solid waste dumping (Deekshatulu 1985). Spectral band of 0.8-1.1 Mm gives much better information on the water bodies. Lineament mapping is also a very important aspect in ground water pollution assessment studies as these structures act as the master conduits for pollutant migration (Ramaswamy and Balaji, 1993).

6.6. EARLIER STUDIES


The application of remote sensing for ground water exploration has
started from the work of Ray (1960). Extensive hydrogeological studies have
been and are being carried out using remote sensing techniques by the Space
Application Center, Indian Space Research Organization, National Remote
Sensing Agency, National Natural Resource Management System, Regional
Remote Sensing Service Center and Karnataka Remote Sensing Technology
Utilization Center, Bangalore. Studies on water resources and management
using remotely sensed data have been carried out by Balakrishna (1986, 1987),
(1983), Moore et al (1975), Meijerink (1996), anon (1990), Baweja et al
(1990), Libatao et al (1990), Obeydkov (1990), Sommen (1990), Medeiros
techniques in ground water exploration in hard area have been also been done
by Sathyanarayana Rao (1983). Works on the applications of LANDSAT data
for hydrogeologic modeling have been carried out by Rango et al (1983), Davis
Per Sander et al (1997) attempted to use the satellite data to analyse different methods of reducibility testing for groundwater exploration. The use of stereo aerial photo interpretation was described by Goosen (1978) for soil mapping. Verstappen (1977) used the data products for the study of geomorphology and similarly, Way (1978) and Townshend (1981) used them for terrain analysis and physiography.

6.7. REMOTE SENSING FOR REGIONAL GEOLOGICAL MAPPING

The IRS-1C and 1D data of WiFS, LISS-III and PAN sensors are found to be highly useful for geological mapping. The WiFS camera provides the synoptic coverage of large areas useful for regional scale mapping and understanding. The multispectral LISS-III data with a spatial resolution of 23.5m is useful for semi detailed mapping upto 1:50,000 scale. The panchromatic data are found to be useful for a detailed mapping upto the scale of 1:12,500. Finer geological features like the traces of bedding and minor joints can be easily identified and mapped.

6.8. IMAGE INTERPRETATION FOR LINEAMENT AND STRUCTURES

There are basically two stages in an image interpretation and study of lineaments.

1. The correct identification of lineaments that represents crustal fracturing or linear zones of thick unconsolidated, coarse material that may overlie buried structures.
2. The correct interpretation and assessment of these features with regard to their like control on the groundwater flow. (Waters, 1990).

Some of the main factors that control the analysis of geological lineaments are as follows:

**Stage 1:**

1. The Scale of the imagery used.
2. The density of non-geological features present.
3. The orientation of important geological feature.
4. The surface expression of important geological features.

**Stage 2:**

1. The subsurface morphology of the lineaments.
2. The hydrogeological function of lineaments.
3. The amount of ancillary information available.

The initial image analysis for lineaments should be performed with no prior knowledge of the detailed geology, geomorphology or hydrology of the area. This is in order to avoid introducing any operation basin in to an interpretation.

The procedure (Pauline Waters, 1990) involves tracing all the lineaments observed over an aerial photographs or satellite image on to a overlay of temperature stable transparent film. During this process the image is viewed vertically and obliquely, in either transmitted or reflected light. This is
repeated for each photograph on at least four separate occasions. On each occasion, the photographs is rotated and viewed from different directions. For example, on the first occasion, the photographs is viewed along the south-north direction and then rotated slightly. Elongated lines orienting in different direction are traced simultaneously. Only those lines that features out from two, or more of the above said analyzed are, included in the final lineament map. Before the map is finally constructed, it is useful to mount the photographs on the wall at eye level. This enables the image to be viewed from a distance and from all directions. In this way many more lineaments can be detected.

The map is then screened to remove all man-made lineaments. These include roads, railways, canals or straight drainage channels and field boundaries. The method used for this is to make a comparison of all these features with the 1:50,000 topographic map. The lineament map and the cultural map are reproduced at the same scale and registered with certain reference points common to both.

Relationship between certain image characteristics (Marianthi Stefouli, 1990) and the geologic nature of the linear features are indicated as:

1. Faults are expressed as pattern variation on either sides of the fault.
2. Presence of faults and fractures show a change in texture.
3. These structures are also expected to show many variations in relief depending upon the displacements.
FIG. 6.2. REVIEW OF VISUAL AND DIGITAL PROCESSING OF REMOTE SENSING DATA

DIGITAL INTERACTIVE IMAGE ANALYSIS TECHNIQUE
MAP 6.1a
GUNDLUPET TALUK
HYDROGEOLOGICAL MAP

LEGEND

- Moderately weathered pediplain
- Shallow weathered pediplain
- Pediment lineament

N

0 5 Kms

60°24' 76°50'

60°24'

60°50'

N
4. Longitudinal contacts are expressed as typical boundaries with two or more textures and tones.

For proper interpretation of an image, a thorough knowledge of the type of geologic structure and the lithology of the area is also needed (Marianthi Stefouli, 1990). IRS-1B satellite image mosaic plate 6.1. and in conjunction with toposheet and field check the major and minor lineaments of the taluk are delineated. And also used for preparing the hydrogeomorphological map showing pediplain and pediments, and land use and land cover map demarcating vegetation, forest, land with scrub and barren and lakes/ water body, (IRS-1B, 26th January 1994, topographic sheets 58A/5, A/6, A/9, A/10, A/13 and A/14n scale 1:50,000.

6.9. IMAGE INTERPRETATION FOR HYDROGEOMORPHOLOGY

The summer season satellite image and survey of India toposheets are the main input for the preparation of hydrogeomorphological map. The geomorphic units are to be delineated based on the image characteristics. A base map prepared on a transparent tracing film is placed over a geocoded image and with the help of a light table, the geomorphic units and form, the structural information like folds, faults, fractures, lineaments and structural trend lines and the lithology are identified and incorporated. The regional geological maps, available literature and other field observations are used in enriching the geomorphological map is given in Fig. 6.2 and map 6.1a. The
<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Geomorphic units / forms</th>
<th>Structure</th>
<th>Materials / lithology</th>
<th>Description</th>
<th>Ground water prospects</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Structural hills</td>
<td>Associated with folding, faulting, etc.</td>
<td>Varying lithology</td>
<td>Linear to arcuate hills showing definite trendlines</td>
<td>Moderate along valleys</td>
</tr>
<tr>
<td>2.</td>
<td>Linear ridges</td>
<td>May be strike controlled</td>
<td>Varying lithology</td>
<td>Linear narrow low lying relief generally barren</td>
<td>Poor</td>
</tr>
<tr>
<td>3.</td>
<td>Structural valley</td>
<td>Linear / curvilinear feature formed as a result of faulting / fracturing etc.</td>
<td>Forms over various lithounits</td>
<td>A linear arcuate valley between the high relief controlled by structure</td>
<td>Good depending on nature of fracture</td>
</tr>
<tr>
<td>4.</td>
<td>Plateau</td>
<td>May be criss-crossed by fracture/joints, lineaments</td>
<td>Forms over various lithounits</td>
<td>Essentially formed over horizontally layered rocks. Marked by extensive flat top and steep slopes</td>
<td>Good to moderate along fractures / joints / lineaments especially their interactions</td>
</tr>
<tr>
<td>5.</td>
<td>Dissected plateau</td>
<td>May be criss-crossed by fracture / joints, lineaments</td>
<td>Varying lithology</td>
<td>Deep valleys / gullies with gently sloping and developing due to stream / river erosion on plateau</td>
<td>Moderate to poor</td>
</tr>
<tr>
<td>6.</td>
<td>Mesa</td>
<td>May consist of volcanic / sedimentary rocks</td>
<td>Varying lithology</td>
<td>Formed over horizontally layered rocks. Flat topped, isolated relief with gentle side slope at the base and steep at the top</td>
<td>Poor</td>
</tr>
</tbody>
</table>

Continued...
<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Geomorphic units / forms</th>
<th>Structure</th>
<th>Materials / lithology</th>
<th>Description</th>
<th>Ground water prospects</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.</td>
<td>Fault</td>
<td>Definite linear features with displacement. It may cut across various lithounits</td>
<td>-</td>
<td>Fracture in the earth crust along the plane of which there either horizontal / vertical / oblique</td>
<td>Good to moderate depending on nature and intensity.</td>
</tr>
<tr>
<td>8.</td>
<td>Fault inferred</td>
<td>Linear features with displacements. It may cut across with various lithounits</td>
<td>-</td>
<td>Possibility of faulting / fracturing is from surface feature</td>
<td>Good to moderate</td>
</tr>
<tr>
<td>9.</td>
<td>Fracture</td>
<td>Cuts cross various lithounits as minor linear features</td>
<td>-</td>
<td>Cracks developed in the country rocks</td>
<td>Good to moderate</td>
</tr>
<tr>
<td>10.</td>
<td>Fracture / faultline valley</td>
<td>Valley formed along fracture / faults</td>
<td>-</td>
<td>Fracture / faulting controlled valley with or without valley fills</td>
<td>Good</td>
</tr>
<tr>
<td>11.</td>
<td>Structural trends</td>
<td>Litho units may be folded / faulted and fractured</td>
<td>-</td>
<td>Structural feature that is arcuate / circular folded</td>
<td>Good to moderate depending on intensity of fractures and valley fill thickness.</td>
</tr>
<tr>
<td>12.</td>
<td>Butte</td>
<td>May consists of volcanic / sedimentary rocks</td>
<td>Flat topped isolated relief with steep sides. Smaller in dimension when compared to Mesa</td>
<td>Poor</td>
<td></td>
</tr>
</tbody>
</table>
TABLE: 6.4. – HYDROGEOMORPHIC UNITS OF FLUVIAL ORIGIN –
AFTER IMSD 1995

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Geomorphic units / forms</th>
<th>Structure</th>
<th>Materials / lithology</th>
<th>Description</th>
<th>Ground water prospects</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Alluvial plain</td>
<td>-</td>
<td>Constitutes gravels, sand, silt and clay of varying lithology, silt dominates</td>
<td>Formed by extensive deposition of alluvium by major river systems. This unit is normally flat / gently undulating surface.</td>
<td>Excellent</td>
</tr>
<tr>
<td>2.</td>
<td>Older / upper alluvial plain</td>
<td>-</td>
<td>Predominantly of gravel, sand, silt and clay of varying lithology</td>
<td>Flat / gently undulating surface formed by river action, older refers to earlier cycle of deposition and upper occupies higher elevation</td>
<td>Excellent</td>
</tr>
<tr>
<td>3.</td>
<td>Younger lower alluvial plain</td>
<td>-</td>
<td>Predominantly of gravel, sand, silt and clay of varying lithology</td>
<td>Like older alluvial plain; but younger refers to late cycle of deposition and lower refers lower elevation</td>
<td>Excellent</td>
</tr>
<tr>
<td>4.</td>
<td>Food plain</td>
<td>-</td>
<td>Primarily comprises of unconsolidated materials like gravels, sand, silt, sand dominates</td>
<td>A flat surface adjacent to a stream / river composed of unconsolidated fluvial sediments. Normally subject to periodic flooding by parent stream / river.</td>
<td>Very good</td>
</tr>
<tr>
<td>5.</td>
<td>Valley fill</td>
<td>Valley are mostly fracture controlled</td>
<td>Constitutes boulders, cobbles, pebbles, gravels, sand and silt</td>
<td>The unconsolidated sediments deposited by streams / rivers normally in a narrow fluvial valley.</td>
<td>Very good, depending on the thickness of fill the prospects varies</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Geomorphic units/forms</th>
<th>Structure</th>
<th>Materials / lithology</th>
<th>Description</th>
<th>Ground water prospects</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.</td>
<td>Deltaic plain</td>
<td>-</td>
<td>Consists of materials from river borne sediments mostly alluvium</td>
<td>Flat to gently sloping plain of large arid extent of thick sediments with fan shape formed at the end of river cycle. (Older / Younger refers respective age / time of deposition; upper / lower refers to elevation)</td>
<td>Very good to good</td>
</tr>
<tr>
<td>7.</td>
<td>Wadi</td>
<td>-</td>
<td>Mainly sand</td>
<td>Wide river beds devoid of water seen in semi arid areas</td>
<td>Good to moderate</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Geomorphic units/forms</th>
<th>Materials / Descriptions</th>
<th>Groundwater prospecting</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.</td>
<td>River Terraces</td>
<td>Comprises of gravels, sand and silt of river borne deposits</td>
<td>Good to moderate</td>
</tr>
<tr>
<td>9.</td>
<td>Revine</td>
<td>Comprises of fine grained semiconsolidated alluvium</td>
<td>Poor</td>
</tr>
<tr>
<td>10.</td>
<td>Old meander</td>
<td>Sand, gravel, Pebble and silt</td>
<td>Excellent</td>
</tr>
<tr>
<td>11.</td>
<td>Palaeochannel</td>
<td>Comprises of fluvial deposits of varying grain size and lithology</td>
<td>Excellent</td>
</tr>
<tr>
<td>12.</td>
<td>Ox-bow lake</td>
<td>Composed of alluvial deposits of varying grain size and lithology</td>
<td>Excellent</td>
</tr>
<tr>
<td>13.</td>
<td>Meander scar</td>
<td>Composed of alluvial deposits mostly silt and clay</td>
<td>Excellent</td>
</tr>
<tr>
<td>14.</td>
<td>Natural levee</td>
<td>Constitute mostly sand and silt</td>
<td>Good</td>
</tr>
<tr>
<td>15.</td>
<td>Back swamp</td>
<td>Comprises of alluvial deposits: Predominantly clay and silt</td>
<td>Good</td>
</tr>
<tr>
<td>16.</td>
<td>Point bar</td>
<td>Comprises of alluvial deposits predominantly by sand and silt</td>
<td>Very good to good</td>
</tr>
<tr>
<td>17.</td>
<td>Alluvial fans</td>
<td>Constitute mainly colluvial material such as gravels, sand, silt, clay etc. of varying lithology. Alluvial fans are somethings characteristics of tectonically active region</td>
<td>Good</td>
</tr>
<tr>
<td>Sl. No.</td>
<td>Geomorphic units/forms</td>
<td>Structure</td>
<td>Materials / lithology</td>
</tr>
<tr>
<td>--------</td>
<td>------------------------</td>
<td>-----------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>1.</td>
<td>Denudational hill</td>
<td>Joints, fractures, lineaments etc</td>
<td>Varying lithology</td>
</tr>
<tr>
<td>2.</td>
<td>Residual hill</td>
<td>Joint, fracture, lineaments etc.</td>
<td>Varying lithology</td>
</tr>
<tr>
<td>3.</td>
<td>Intermontane valley</td>
<td>Sometimes fracture controlled</td>
<td>Constitutes colluvial deposits of varying lithology</td>
</tr>
<tr>
<td>4.</td>
<td>Pediment</td>
<td>Sometimes fracture controlled</td>
<td>Varying lithology</td>
</tr>
<tr>
<td>5.</td>
<td>Pediment in Selbergs complex</td>
<td>Sometimes controlled by joints, fracture lineaments etc.</td>
<td>Varying lithology</td>
</tr>
<tr>
<td>6.</td>
<td>Pediplain</td>
<td>Sometimes controlled by joints, fracture lineaments etc.</td>
<td>Varying lithology</td>
</tr>
<tr>
<td>7.</td>
<td>Buried pediment</td>
<td>Fracture may be present</td>
<td>Unconsolidated weathered materials of varying lithology</td>
</tr>
<tr>
<td>8.</td>
<td>Buried pediplain</td>
<td>Crisscrossed by fractures / faults etc.</td>
<td>With varying thick overburden of weathered material of varying lithology</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Sl. No.</th>
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<th>Structure</th>
<th>Materials / lithology</th>
<th>Description</th>
<th>Groundwater prospects</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.</td>
<td>Buried pedplain / Buried pediment shallow</td>
<td>May be crisscrossed by lineaments / fractures</td>
<td>With shallow overburden of weathered material of varying lithology</td>
<td>Flat and smooth surface of buried pedplain / pediment with (0-5m thickness) shallow overburden</td>
<td>Moderate to poor</td>
</tr>
<tr>
<td>10.</td>
<td>Buried pedplain / Buried pediment medium</td>
<td>May be crisscrossed by lineaments / fractures</td>
<td>With moderately thick overburden of weathered material of varying lithology</td>
<td>Flat and smooth surface of buried pedplain / pediment with moderately thick (5-20) overburden</td>
<td>Moderate to poor</td>
</tr>
<tr>
<td>11.</td>
<td>Buried pedplain / Buried pediment medium</td>
<td>May be crisscrossed by lineaments / fractures</td>
<td>With very thick overburden of weathered material of varying lithology</td>
<td>Flat and smooth surface of buried pedplain / pediment with very thick (more than 20) overburden</td>
<td>Good</td>
</tr>
<tr>
<td>12.</td>
<td>Laterite upland</td>
<td>-</td>
<td>Mainly laterites as capping over granite, metasediments</td>
<td>Higher elevated flat land with laterite capping</td>
<td>Poor</td>
</tr>
<tr>
<td>13.</td>
<td>Dissected Laterite upland</td>
<td>-</td>
<td>Mainly lateriteras capping over granite, metasediments</td>
<td>Higher elevated land with Lateritic cappings with extensive dissections marked by gullies and broad shallow valleys</td>
<td>Poor</td>
</tr>
<tr>
<td>14.</td>
<td>Piedmont</td>
<td>-</td>
<td>Constitutes boulders, cobbles, pebbles, gravels, sand, silt and clay of varying lithology</td>
<td>Formed by coalescence of several fans by stream covering large area at the foot hills, with gentle slopes, in humid to sub humid regions (upper humid to sub humid regions). Upper and lower units are marked by variation in slopes and thickness of sediments</td>
<td>Good to moderate</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Geomorphic units/forms</th>
<th>Structure</th>
<th>Materials / lithology</th>
<th>Description</th>
<th>Groundwater prospects</th>
</tr>
</thead>
<tbody>
<tr>
<td>15.</td>
<td>Bajada</td>
<td>-</td>
<td>Comprises detrital materials of varying grains size and lithology</td>
<td>Coalescence of alluvial fans at the foot hills in arid and semiarid regions having gentle slopes. (Upper and lower units are marked by variation in slope and thickness)</td>
<td>Good to moderate</td>
</tr>
<tr>
<td>16.</td>
<td>Dyke</td>
<td>-</td>
<td>Various basic and acidic intrusives like Dolerite, Basalts, Pegmatites etc.</td>
<td>A discordant mass of consolidated series of intrusions that cut across the country rock. It may act as barrier and control the flow of groundwater depending upon topography and local hydrological condition</td>
<td>Good to moderate on upper side</td>
</tr>
<tr>
<td>17.</td>
<td>Inselberg</td>
<td>-</td>
<td>Varying lithology</td>
<td>Residual isolated hill stand above the ground level of surrounding pediplain: normally barren and rocky Rock debris</td>
<td>Poor</td>
</tr>
<tr>
<td>18.</td>
<td>Talus cone</td>
<td>-</td>
<td>Comprises screen or rock fragments</td>
<td>Accumulated at the foot of steep slopes and cliffs which have originated from the parent rock mass under the influence of gravity.</td>
<td>Poor</td>
</tr>
</tbody>
</table>
notable hydrogeomorphic units of structural, fluvial and denudational origin and their lithology and groundwater conditions as analyzed by several workers are given in the Table 6.3 to 6.5.

The IRS-1B images captured in January 1994 and the Survey of India toposheet of 1:50,000 scale, have been used for the preparation of hydrogeomorphological map of the present study area. The available geological map followed by an intensive field check has helped in the identification of various units (Map 6.1a).

6.10. REMOTE SENSING AS A TOOL IN GROUNDWATER EXPLORATION

Satellite data have been proved to be highly useful for groundwater studies and mapping. Remote sensing is an excellent tool for the hydrogeologist and geologists to better understand and the perplexing problems of groundwater exploration (Lamoreaux; 1984). But groundwater by its very nature is not available for direct observation (Farnsworth et al 1994). This remotely sensed data cannot be used directly but require substantial and to some extent subjective information about an area to be collected by the interpreter. Shapes, patterns, tones and textures identified through image analysis provided direct or indirect evidence of features of hydrogeological interest. These include structures (faults, joints, ductile shears, folds), intrusions (dikes, veins), distribution of solid and unconsolidated lithologies, morphology
(landforms, erosion surfaces, basin of deeper weathering, present of ancient drainage systems and pattern, presence of hygrophile and hydrophile vegetation and areas of preserved soil moisture during dry-season conditions.

There are basically two approaches in the use of remote sensing as a ground water exploration technique. The first approach relates the pattern surface and groundwater flow considering the structures, drainages and physiographic conditions. The second approach relates to the well yields, along the structurally deformed zones. Well yields often show a positive correlation with linear features or with interaction between two features. IRS-1B satellite imagery has been analyzed for the identification of lineaments and surface water bodies and is explained in Map 6.3.

6.11. GEOGRAPHICA INFORMATION SYSTEM (GIS)

A Geographical Information System (GIS) as defined by the National Science Foundation is a computerized data base management system used to capture, storage, retrieval, analysis and display of spatial (e.g. locationally defined) data. The technology can be used to overlay and combine into a single computerized map that can summarized geographic, cultural and scientific land attribute. With the release of software MAP/INFO, a popular GIS software, there is a tremendous user base with a myriad of application ranging from high level cartography to land use planning, natural resource arrangement,
agriculture, forestry etc. The GIS was used to perform analysis that were previously too costly or not feasible.

To illustrate this, consider the information needs of a hydrogeologist who wishes to study the erosion and sedimentation in a watershed. In such an application, it is critical to be able to identify the likely sources of sediment. At a minimum, this identification process would involve the study of topographic slope, soil erodability, and surface runoff characteristics on area if, topographic maps, detailed soil survey maps, and land cover maps exist for the area, the analyst would have the raw data needed for the study. However more often than not, the maps will be at a compatible scales. Besides the scale problem the analyst in this case needs the information derived from the existing map sources, instead or original mapped data. That is slope information must be derived from land cover. Hence the following tasks have to be performed to develop a information base for the analysis

i. For each data source, the map sheets covering the area should be carefully joined together to form one large sheet for each type of data (contours, Soils, land cover). The boundary of the area would then be delineated on each data map and the map should be converted to common scale.

ii. Next necessary information would be derived from the source map. Slope information would be determined from the contours shown on
the topographic map. The soil erodability would be derived from the soil map and runoff potential would be derived from the land cover.

iii. The analyst would then have to merge the three sets of derived information. This involves interrelating the information sets through the area to locate the areas where combinations of site characteristics indicate high soil erosion potential.

The information merging procedure was historically performed by a map overlay method. First each derived data set was prepared on a transparent map sheet. These maps were coded in grey tones according to the degree of the conditions being depicted. The darkest areas on the composite map would indicate a combination of factors representing high potential sediment source areas.

The principal advantages of the map overlay methods are that it requires little specialized equipment. However, certain difficulties are inherent in this approach. The task of bringing this data to a common scale format and deriving applicable characteristics are time consuming and expensive, because they are tailored to a specific analysis, the overlay sheets may not be applicable to the other studies. It is difficult to quantify the results of the overlay analysis, since Manual computation of areas on the composite map can be extremely time consuming.

The difficulties of manual overlay techniques are greatly reduced by a computer coding the land information. Land related data recorded according to
location are called Georeferenced data or Geocoded data. A spatially ordered collection of such data is called a Geobased file.

Computer analyzation of Georeferenced data in the study of soil erosion potential. In this illustration, the data maps (a) are computer coded with respect to a grid (b). The data maps are encoded by recording the information category most dominant in each cell. That is, each cell is assigned a single soil type in the soil data file, a single land cover type in the land cover file and an average elevation in topographic file. The task of geocoding the data can be tedious and costly. Yet once this task is accomplished, the analysis of geocoded data can be performed quickly and accurately. The job of interpreting characteristics (such as slope, erodability, runoff) from the original data is simple one for the computer can calculate areas by simple counting grid cells and multiplying the area of each cell. If the database also contained information on land ownership, the land owners is the greatest problem areas can be identified.

A host of analysis may also be performed on geocoded data. For example perspective view of the landscape from the topographic data file can be derived. Proposed changes in vegetation cover and topography can be analysed in this manner evaluate the visual impact of the changes.

6.11.1. Points, Lines and Polygons

All geographical data can be reduced to three basic topological concepts, which are in GIS-point, lines and polygons (areas).
The above graphical components are referenced and stored in terms of a spatial referencing network, which enables different types of graphical data to be linked together. There are many different types of spatial referencing system (e.g., grid square, geographical co-ordinates-Latitudes and Longitudes, grid co-ordinate X&Y or Easting or Northing), which can be used as geographical location of graphical entities or points.

6.11.2. Components of GIS

The GIS has three important components viz. computer hardware, set of application software modules and a proper organizational context. These three components should be in balance if the system is to function satisfactorily.

6.11.3. GIS Software Modules

The software package for GIS consists for five basic technical modules, which are shown, in Fig.6.3. These basic modules are sub system for

a. Data input/Encoding

b. Data storage and data management

c. Data manipulation and retrieval

d. Data output and presentation

6.11.4. Data Input

Data input is the procedure of encoding the data into a computer readable form and writing the data into a GIS database. The data to be entered into GIS are of two types-Spatial data and associated non-spatial data. The
FIG. 6.4 DATA INPUT
spatial data represents geographic features. Points, lines and areas are used to represent geographic features like a lake, a street or a forest. The non-spatial attributes data gives descriptive information like the name of the street, the salinity of the lake, or the composition of the forest land.

Fundamentally, there are two different ways in which graphical data can be encoded in the computer viz. (1) THE GRID CELL or RASTER format (2) POLYGON or VECTOR format. To reiterate, the dominant information class is recorded for each cell in the data matrix. Finer the grid used the more geographic specificity there will be in the data file. A coarse grid requires less accurate geographic description of the original data.

Data input as shown in Fig 6.4. Covers all aspects of transforming data captured in the form of existing maps, field observation and data obtained from sensors (including storing aerial photographs, satellite into a compatible digital form). There are many method by which geographic data may be computer coded or digitized. There are four types of data entry systems commonly used in a GIS:

1. Keyboard entry
2. Co-ordinate geometry
3. Manual digitizing
4. Scanning
Keyboard entry involves manually entering the data at a computer terminal. Attribute data are commonly input by keyboard, whereas spatial data are rarely entered in this way. In co-ordinate geometry procedures (COGO) the survey data are commonly entered by keyboards. From these data the co-ordinates of the spatial features are calculated and a GIS compatible data file is created.

Manual digitizing is the most widely used method for entering spatial data from maps. The map is mounted on a map features. A smaller device, termed a digitizing tablet is commonly used as a device to operate the GIS. The digitizing table electronically encodes the position of pointing of pointing device with a precision of fractions of millimeters. The most common table digitizer uses a fine grid of wires embedded in the table. The cursor normally has a crosshair for precise positioning and 16 or more control buttons that are used to operate the data entry software and to enter attribute data.

The efficiency of the digitizing depends on the quality of the digitizing software and the skill of the operator. The process of tracing lines is time consuming and error prone. Attribute data may be entered during the digitizing process, but usually only an identification number is coded. The attribute information referenced to the same identification number is coded. The attribute information referenced to the same identification number are then entered separately.
6.11.5. Manual Digitization

Manual digitizing is the tedious job. Operator fatigue can seriously degrade the data quality. Work scheduling should limit the hours per day that an individual spends digitizing and suitable quality assurance procedures should be used to ensure that the digitized data and the associated attribute data satisfy the required accuracy standards. A commonly used quality check is to produce a verification plot of the digitized data that is visually compared with the map from which the data were originally digitized.

6.11.6. Scanning

Scanning provides a faster means of data entry than manual digitizing. In scanning, a digital image of the map is produced by moving an electronic detector across the map surface. Two scanner designs are commonly used in a flat bed scanner. The map is placed on a flat scanning stage over which the detector is moved in both x and y directions. In a drum scanner the map is mounted on a cylindrical drum. The detector is moved horizontally across the drum as it rotates. The sensor motion across the drum provides the movement in the X direction. The drum rotation provides the movement in the Y direction.

The output from the scanner is a digital image. The fineness of detail capture by the scanner depends on the size of the map area viewed by the
detector, termed the spot size. The raster image is computer processed to improve the image quality and is then edited and checked by an operator. During the editing procedure, each spatial element is tagged and assigned an identification number. The attribute data are linked to the spatial data by means of these identification numbers.

6.11.7. Scanning vs. Manual Digitizing

Data entry using scanning is claimed to be 5 to 10 or more times faster than digitizing. Maps normally must be redrafted before they can be scanned. Redrafting is often considered to be a major disadvantage of the scanning option. While a scanning system is for the most part automated and so requires less highly trained personal for the same tasks, more complex equipment must be written or purchased, more sophisticated software to edit and clean the raster data and then to convert the raster data into the vector form.

Scanning works best with maps that are very clean, simple, and don’t contain extraneous information, such as text or graphic symbols. It is more cost effective for maps with large number of spatial elements and maps with larger number of spatial elements and maps with larger number of irregularly shaped features.

Manual digitizing tends to be more cost effective when there relatively few maps that is not in a form that can be scanned. Maps, which contain a lot
of extraneous information, require interpretation or adjustment during the encoding process, or have, as small numbers of features to be encoded are generally not with scanning.

6.11.7. Geographic Analysis

In geographic analysis, it is needed to study real world processes by developing and applying models. Such models illuminate underlying trends in geographic data, making new information available. A GIS enhances this process by providing tools, which can be combined in meaningful sequences to develop new models. These models may reveal new or previously unidentified relationships within and between data sets, increasing our understanding of the real world.

Maps, reports, or both can communicate the results of the geographic analysis. A map is best used to display geographic relationships, whereas a report is most appropriate for summarizing the tabular data and documenting any calculated in your geographic data use.

Before starting any analysis, it is needed to assess the problem at hand and establish an objective. Think through the process before making judgment about the data or reaching any decisions. Ask question about the data and the model. Generate a step by step procedure to monitor the development and
outline the overall objective. The basic procedure to be carried for geographic analysis is given below:
Step: 1 establishment of the objectives and criteria for the analysis.
Step: 2 preparations of the data for spatial operation.
Step: 3 perform the spatial operation.
Step: 4 preparations of the derived data for tabular analysis.
Step: 5 perform the tabular analysis
Step: 6 evaluation and interpretation of the results.
Step: 7 refinement to the analysis as needed.

6.11.9. Data Storage and Data Base Management

Data entered into GIS are stored in a data and the management of the data in a database is performed by a DBMS, which organizes the data in appropriate data structure for efficient processing and retrieval. The most commonly used DB system in GIS is the relational DBS which establishes the relationship between thematic elements from the attribute data base and spatial elements from the map or image DB.

6.11.10. Data Manipulation / Retrieval

This component of the GIS is the key for extracting meaningful information from GIS, DB, by way of logical queries. Few of these could also be in the form of basic functions like scale changes, distortion removal, transformation, co-ordinate translation and projection changes etc., map
FIG. 6.5 DATA OUTPUT

DISPLAY AND REPORTING

Magnetic Media

Plotter

Printer

Visual Display Terminal

TABLES

FIGURES

MAPS
overlay, map intersection, area calculation, line length measurement, proximal
searches, text placements, curve fitting, windowing etc., are few functions
which from as GIS manipulation components. These basic functions in general
are associated with various types of retrieval options.

6.11.11. Output

Output is the result by which information from the GIS is presented in a
form suitable to the user. Data are presented in one of the three formats. Hard
copy; soft copy; or electronic. Hard copy outputs are permanents means of
display. The information is presented on paper Mylar, photographic film, or
similar methods. Maps and tables are common from of outputs in this format.
(Fig 6.5)

Soft copy output is the format as viewed on a computer monitor. It may
be text or graphics in monochrome or colour. Soft copy output are used to
allow operator interaction and to preview data before final output. The soft
outputs are used to allow operator interaction and to preview data before final
output. The soft copy display is generally not used for final output because of
its small size and the loss in quality when the screen image is photographs or
electrically captured. A soft copy can be changed interactively, but the view is
restricted by the size of the monitor. A large map area can seen but only a
coarser resolution. The hard copy output needs longer time to produce and
requires more expensive equipment. A large map can be shown at whatever level of detail is required by making the physical size of the output larger.

Output in electronic formats consists of computer compatible files. They are used to transfer data to another computer systems either for additional analysis or to produce a hard copy output at remote location.

6.11.12. METHODOLOGY

Satellite images are interpreted using image/photo interpretation keys such as color/tone, texture, pattern shape, size association, drainage, topography etc., to derive hydrogeomorphological maps. This map shows various land forms present in an area such as pediplain, pediment, and fractures/Lineament etc., the texture will vary depending upon terrain (hard rock terrain, alluvial terrain, etc). for each of the landform groundwater prospects is assigned based on type of landform, lithology, structure, soils, land use/land cover, drainage, topography, etc.,

Information on various features like lineament, lithology, landforms, land use/land cover, slopes, drainage, soils etc., are derived using satellite data IRS-1B LISS-III data (1994) in conjunction with collateral data such as SOI Toposheets, 58A/5, A/6, A/9, A/10, A/13 and A/14 in the scale of 1:50,000 and field observations. This information is integrated to assess the suitability of sites of locate the groundwater potential zones.
Interpretations of various parameters, which control the occurrence, and movement of groundwater such as Lithology, structures, landforms etc., are carried out. GIS environment has helped in identifying prospective zones and integration of various thematic maps. All of these help in further necessitating the target areas of potential ground water zones.

ANALYSIS

6.11.13. TOPOGRPAHY AND SLOPE ANALYSIS

The taluk is located on an uneven terrain with maximum and minimum elevations varying between 400-1000 Mts respectively. The higher elevations are observed in the SW and North of the taluk and the lower elevation in the stream courses.

Slope is one of the most important terrain characteristics and plays a vital role in geomorphological and run off processes, soil erosion and Land use planning.

So it is very important to have an understanding of the spatial distribution of slopes for the development and measurement of both land and water resources.
MAP. 6
GUNDLUPET TALUK
SLOPE MAP

LEGEND
- 0 - 1 %
- 1 - 3 %
- 3 - 5 %

N

0 5 Kms

76° 24' 76° 50'
The general slope of the taluk is towards N-E & S-E. Very gently sloping categories (more than 1% and upto 3%) corresponding to weathered portion of the granite gneisses and schist are observed in the N-S part of the taluk. moderate slopes (Gently slopes) more than 3% up to 5% are observed in the SW part and nearly Level 0-1% are observed in the eastern side of the taluk (Map 6).

6.11.14. DRAINAGE AND SURFACE WATER BODIES

In the area drainage represents a fan shaped pattern. The drainage in the taluk is dendritic (6.1) as is common in granite, schist and gneissic terrain, the stream in the taluk are first, second, third and fourth order with a ephemeral stream originating in north and southern part of the taluk and trending towards the outlet located in the eastern side of the taluk.

6.11.15. GEOLGOY AND SOILS

Geographically the taluk is covered by the rocks of Archaen age, i.e., granite, gneisses and schistose rocks (Map.2.2a). They comprise essentially gray to pink granites which also exhibit gneissosity at places the strike of foliation in gneisses is NW – SE with dip towards NE and the schistose rocks are seen on the North /south direction. The rocks are coarse to medium grained and after found porphyritic with phenoicrusts of potash feldspar and schistose rocks shows shistosity.
The study area is covered by two types of solids shallow sandy loam and red loam with gravelly sub soil (Map.2.3).

6.11.16. HYDROGEOMORPHOLOGY

Delineating of various geomorphic units and knowledge about their groundwater play an important role in the optimum utilization of land resources. Besides, the information on landforms and geological information like lithology and structures also help in identifying the groundwater potential zones. The hydrogeomorphological map has been prepared (Map 6.1a) on 1:50,000 scale by demarcating various geomorphic units / land forms, lineaments using satellite imagery and in conjunction with geological map and the survey of India topo sheets & field observation.

6.11.17. DESCRIPTION OF GEOMORPHIC UNITS

Pediplain of Granite, Gneiss & schist with Moderate Weathering.

It is a flat surface of pedipalin of granite gneiss & schist with 20-60 m. thick weathered material and covered with soils. It occupies generally the topographically low areas near stream courses and associated with fractureds lineaments. The ground water prospects in these zones are moderate to good. Very good yields are expected in this zones when associated with fractures / lineaments. Ground water in these units mostly occurs in weathered and fractured zones.
Pediplain of Granite, gneiss, and schist with shallow weathering.

This is a flat surface of pediplain of granite, gneiss & schist with weathering extending up to maximum depth of 20, and covered with the soils. These units generally occupy relatively elevated regions and occasionally associate with fractures / Lineament. Poor to moderate yields of ground water are expected in these units will help to sink a dug wells. In general, the yields of the wells located in these units are found to be 100-200 m$^3$/d.

Pediments of granites, gneiss and schist

It is a flat surface of erosional bedrock of granite, gneiss & schist with veneer of detritus. These units mostly act as run off zones or recharge areas. Groundwater prospects in these units are less than 100m$^3$/d or sometimes dry.

Fractures / Lineaments

The various geomorphic units in the study area are traversed by lineaments vertical to sub-vertical and horizontal to sub-horizontal deep-seated fractures. The fractures in the study area are generally associated with topographical depressions and controlling drainage network. These are trending in N-S, NNE-SSW, NNW-SSW, NW-SE, NE-SW and E-W directions. The depth of weathering is more in the areas traversed by lineaments and fractures. Hence, these fractures play a vital role in the development of ground water in the study area.
LEGEND
- Forest
- Vegetation
- Barren Rock / Stoney Waste
- Land with or without scrub
6.11.18. LAND USE / LAND COVER

A comprehensive information of land use / use cover is the basic prerequisite for land resource evaluation, assessment, utilization and management. The various land use / land cover classes occurring in the study area are described below (Map 6.2)

Description of land use / land cover classes

The various land use / land cover classes delineated in the taluk are (1) vegetation (2) forest (3) land with or without scrub (4) barren rock / stony waste (7.2).

Vegetation

This is area with various kinds of vegetation seen in the area and there are two classes

1. Cultivation land:

These are the cultivated lands in the area. It is seen that these lands are near to the drainages. Short duration crops are more cultivated than the long duration ones. Long duration crops are concentrated in the eastern part of the study area cultivated land measures about 9272 hectares.

2. Tree and Groves:

In this area commonly grown or planted trees and groves are coconut trees and Eucalyptus grandis. Measures about 822 hectares.
Forest

Bandipur has a forest area 2516 hectare. Which comes under the control of the forest department the forest are classified as reserved and protected. In an area most of the forest belongs to the reserved forest with a flora of Acacia, Albizia, Hardwickia, and Tectona Dillenia, Eucalyptus grandis and grassy meadows and low wooded patches exist in the area. Fauna with wild pig, wild dog, cats, good herds of black bucks, peacocks, wolves and foxes exist in the area.

Land with or without scrub:

It is the land which has an undulating topography with thin soil cover and scattered trees / scrubs. This land use class occurs in two categories (a) cultivable waste 26178 hectares and (b) permanent pasture 495 hectares. These lands are being used for grazing and are ideal sites for plantations. The total area under this category is calculated as 26,673 hectares.

Barren rock /stony waste

It is the land, which has an undulating terrain with the rocks; exposed on the surface, which is not suitable for any agricultural activity, the calculated area is 6886 hectares.
6.11.19 Others

Water bodies

These are the areas of impounded water often with a regulated flow of water, these include streams, tanks, etc., (Map 6.1&6.3) and tanks are the important surface water bodies. There are 60 tanks in the taluk under study. In general tanks are rain fed and are interconnected by streams at few places water from these tanks is mainly utilized for agricultural and drinking purposes. The area irrigated by tanks is 4.097 hectares.