CHAPTER – II

GEOL OGY

2.1 INTRODUCTION

In the hydrogeological studies a thorough knowledge of the lithological and structural features of the region is very essential. The above understanding enables the groundwater researcher to analyze and evaluate the groundwater resources both qualitatively and quantitatively. The storitivity and sub surface flow differ with various geological conditions. Hence a comprehensive knowledge on the geology of the study area is an important.

2.2 GEOL OGY OF TAMILNADU

Pre-Cambrian crystalline rocks cover over 80 % of the terrain and Phanerozoic sedimentary rocks cover the eastern coastal terrain and river valleys amount for the rest (Fig.2.1). Within this, vast array of crystalline rocks, igneous emplacement of anorthosites, granites, syenites, carbonatites, Ultra mafic bodies and basic sills and dykes occur. Phanerozoic rocks of fluviatile, fluvio-marine and marine origin occur along the eastern coastal belt (Subramanian et al., 2001).

2.3 GEOL OGY OF LOWER GUNDAR BASIN

Lower Gundar river basin comprises of Archaean crystalline rocks on the north and northwestern parts and Tertiary sedimentary formations in north, northeast and western parts while recent to sub recent age sediments from central to southern portions (Fig. 2.2).
Archaean being oldest of this region, it comprise of hornblende biotite gneiss, mica gneiss, feldspathic gneiss, garnetiferous gneiss, pegmatite and quartzites. The regional foliation of these rocks varies from NNE – SSW to WNW – ESE and E – W directions with dip of SE, NE and South directions. The dip amount varies from 40° to 70° and rarely it is vertical too. These rocks are dark coloured, coarse grained, friable and highly weathered (Varadaraj et al., 1986). Occasionally, they are sheared and contorted. The tertiary formations occurring in this area are similar to Cuddalore formations (Mio Pliocene). These calcareous sand stones are in general horizontally bedded and occur unconformably over the Archaean basement (Singh et al., 2002) and they are exposed in the north and western region of Kamudi as broad elevated high ground. It is also exposed in north of Tiruchuli. Kankan occurs along the stream courses, indicating higher evaporation.

The major part of the study area is covered by alluvium brought by the rivers flowing from the west of this region. Marine and fluvio – marine sediments occur in southern portion. Laterites are seen as patches within these marine sediments. Sedimentation has taken place under fluvial and fluvio – marine and aeolian environments.

Sub – recent marine formations consisting of hard calcareous sandstone and grey clays etc. are seen along coastal tract. The kankan contains translucent Ca CO₃ in the form of calcite in the core and buff to white admixed with chert and sand grains in the periphery. Besides sand and sandstone with rounded and angular quartz grains, fine to medium grained with shells and feldspar, garnet, illemanite etc. occur in beach forming dunes (Lawrence, 1995).
<table>
<thead>
<tr>
<th>Era</th>
<th>Period</th>
<th>Formation</th>
<th>Lithology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quaternary</td>
<td>Sub recent to recent</td>
<td>Alluvium, Laterite, Marine Sediments</td>
<td>Sands, Clays, Silt, Kankar, Laterite, Fluvio – marine Sediments</td>
</tr>
<tr>
<td>Mio – Pliocene</td>
<td></td>
<td>Cuddalore Sandstones</td>
<td>Sand, Sandstone with clay</td>
</tr>
</tbody>
</table>

Unconformity

Azoic  
Archaean  
Younger intrusives  
Pegmatites, Quartzites, Granites, Charnockites

Older Dharwars  
Hornblende Biotite gneiss, Complex gneiss, Calc. gneiss, Quartzites, Basic Metamorphic rocks and Garnetiferous gneiss

(C.G.W.B, 1998)

2.4 Subsurface Geology

In this study, the subsurface geology has been deduced from the litholog details of exploratory bore wells drilled by various organizations involved in groundwater exploration. With the available subsurface data, the depth to the basement has been deduced. Two sections have been prepared of which one (A-A’-A”) is virtually parallel to the coast and the other (B-B’) is nearly perpendicular to the coast (Fig. 2.3).
2.4.1 Geological Section Along A – A’ – A"

The lithology data of the bore wells at Tiruchuli (A), Mandalamanickam (A’) and Mudukulathur (A’’) has been utilized in the preparation of this geological section (Fig.2.4). The depth of the bore wells varies from 20.7 m (bgl) (Mandalamanickam) to 76 m (bgl) (Mudukulathur). The depth to the basement is shallow at northwestern part and increases towards southeast. Very thin sedimentary formations exist above the basement rocks in Mandalamanickam and Tiruchuli. A thick pile of sediment is encountered at Mudukulathur. Kankar bed admixed with sand occurs in shallow depths at Mandalamanickam and Mudukulathur. Hydrogeologically, a medium to coarse grain sand present above the basement forms the aquifer horizon.

2.4.2 Geological Section Along B – B’

The geological section denoted as B – B’ includes the bore wells at Kovilankulam (B) and Sayalkudi (B’’) (Fig.2.5). The depth varies from 74 m (bgl) at Kovilankulam to 100.5 m (bgl) at Sayalkudi. Alternate layering of sandstone and clay is encountered in the section with fine sediments occurring in moderate depth. Crystalline basement is not encountered in these wells.

From these geological cross sections it is understood that, the number of sedimentary formations, their thickness and the depth to the basement increase towards the coast. The clay thickness increases towards south.
Fig. 2.4 Geological Section Along A – A’ – A”

Horizontal Scale: 1.5 cm = 4 Km
Vertical Scale: 1 cm = 10 m
2.5 Remote Sensing and GIS in This Study

Remote sensing refers to the group of techniques of collecting information about an object and its surroundings from a distance without physically contacting them. Normally, this gives rise to some form of imagery, which is further processed and interpreted to produce useful data for application in agriculture, archaeology, forestry, geography, geology, town planning and other fields. The prime objective of remote sensing is to extract environmental and natural resources data related to Earth. Information about the object concerned is conveyed to the observer through electromagnetic energy, which is the information carrier and thus provides the communication link. Basically, remote sensing is regarded as wavelength – intensity information that needs to be decoded before the message can be fully understood. This decoding process is analogous to the interpretation of the remotely sensed imagery, which impinges heavily on our knowledge of the properties of electromagnetic radiation. The Earth’s surface can be viewed and analyzed at a range of scales. At larger map scales the land surface becomes more generalized and the identity of individual objects is lost while larger objects become more significant. The mapping scale generally accepted is 1:50,000 scale. Remote sensing may be used to map, monitor and estimate the properties of environmental phenomena. Of these three areas of application and mapping, particularly thematic mapping, is perhaps the common and may be a prerequisite for the others. Traditionally, classification techniques have been used as the tool for thematic mapping.
The major objective of the remote sensing applications in geology, geomorphology and hydrology is to detect, identify and map the earth features on the surface to infer the processes at work through the synoptic vantage point afforded by the imagery acquired from aerospace platforms. Conventional mapping of groundwater features is a time consuming and expensive process. Remote sensing is a newly emerged technique wherein the use of satellite data is made to narrow down the areas for geophysical exploration and is found to be an effective tool to distinguish the potential area from non-potential zones. Satellite imageries are interpreted visually or digitally to delineate the hydrogeomorphic units, lineament and land use / land cover. Image analysis has a specific utility for mapping of palaeochannels. Features of meander plains, fluvial sediment deposits and vegetation type and texture can indirectly help in demarcating the palaeochannels. Palaeochannels can be identified on any imagery through Photo-characteristics such as shape, liner pattern, medium texture and darker tone (Balakrishnan, 1986). Satellite imageries have been successfully used for the delineation of fluvial features of recent and palaeoriver systems (Ghose et al, 1979; Backliwal & Grover, 1988; Ramasamy et al, 1991; Tiwari, 1992 and Sarma, 1993). Remote sensing is particularly suited for use in studying the dynamic aspect of the terrain features, particularly the genetic origin of landforms in geomorphologic applications.

The integration of remote sensing and Geographic Information System (GIS) in environmental applications has become increasingly common in recent years. Remotely sensed images are an important data source for environmental GIS applications and conversely GIS capabilities are being used to improve image analysis procedures. When
image processing and GIS facilities are combined in an integrated system vector data can be used in image classification and raster image statistics within vectors query and analysis. The term Geographic Information System or its synonym Geographical Information system is referred to the computer information system, which handles geographic data used in substantive applications. The distinct political or administrative boundaries are often imposed for the monitoring and/or control natural areas. Some of them are geology, hydrology, civil engineering, urban planning, site selection analysis, disaster management, environmental analysis, etc. GIS is a powerful set of tool for collecting, storing, retrieving, transforming and displaying spatial data for the real world for a particular set of purposes. The analytical ability of the GIS that distinguishes itself from the other information systems and also the power of a GIS to process the voluminous spatial data and their attributes are unquestionable.

All the maps in this study have been prepared using GIS software such as Arc View, ARC INFO.

2.5.1 Geomorphology

Geomorphology is one of the principle sub-division of geology and deals with the study of the surface configuration of the earth. With the availability of various kinds of satellite imageries at regular intervals, a hydrogeologist is better equipped for mapping and monitoring the various changes that are taking place with regard to the size and shape of the landforms, slope of the terrain, river courses and the drainage networks.
From IRS 1C, LISS III FCC, Geo-coded data on 1: 50,000 scale a geomorphology map of the study area has been prepared and following features have been deduced (Fig.2.6). Coastal plains cover the area along the coast, which is mostly made up of beach sands. It has an elevation ranging from 5 to 10 m (amsl). Sedimentary plain occurs at the north of the coastal plain and extends up to central region. A larger flood plain occupies the central region and adjacent to river Gundar and its tributaries. Sedimentary high land made up of sandstones occurs in the central portion. Pediment exists as isolated patches in northern part of this area. The rest of the region in north and northwest is occupied by buried pediment and upland. The buried pediment and upland lie at an altitude of 85 m. Sand dunes of transverse, longitudinal, crescent shaped and fixed types occur along the coast with a height ranging from 4 to 5 m.

2.5.2 Lineaments and Palaeochannels

Aerial photograph has been especially helpful in locating fractures and faults. A fracture trace is defined as a natural linear feature less than 1 mile (1.6 Km) long that can be identified by aerial photographs. Linear traces that are longer than a mile are called lineaments (Driscoll, 1986). Crustal movement along faults in igneous and metamorphic rock terrains creates rubble zones, in which relatively large volumes of water may be stored. In the past, the success of wells constructed in hard rock terrains was usually considered a matter of chance. Using aerial photographs and later satellite imagery, hydrogeologists now know that well yields in these hard rock terrains depend on the presence of joints, fractures, fault and lineaments. Structural features such as lineaments are also of great importance, since they could be zones of high porosity and permeability.
(Kukkillaya et al, 1999). Thus the fault and lineaments represent the zone of high groundwater potential.

Using IRS imagery, a structural map of the study area have been traced out and validated with field checks (Fig. 2.7). Major and minor lineaments are observed. Major lineaments are trending in the NW – SE direction and minor lineaments differ in the direction locally. Two major faults, one trending NW - SE in the north and the other trending NS in central portion have been identified. River flows along the trends of these faults. Another fault trending N - S is also identified in south. A set of palaeochannels in the middle and east of river course of this region has been confirmed from the satellite imagery. A palaeochannel running in NW – SE near the southern coast has been identified (Lawrence, 1995 and CGWB, 1998).

2.5.3 Land use and Agriculture

Hydrogeologist can evaluate the resource potential by studying the land use, landforms, drainage and vegetation patterns of an area (Driscoll, 1986). A land use map for the study area has been sketched with the help of IRS imagery (Fig. 2.8). The area details of various patterns are listed in table 2.2.

Plantations cover an area of 164.84 Km² mostly along the central and southern region. Dry and wet crops cultivated field occupy an areal extent of 151.73 Km² and 180.20 Km² respectively. The agriculture is the main occupation of the habitants of this area. Agricultural activities of this region are supported by surface and groundwater resources.
## Table 2.2 Details of Land Use and Land Cover

<table>
<thead>
<tr>
<th>Nature of Landform</th>
<th>Area (Km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aquaculture</td>
<td>2.78</td>
</tr>
<tr>
<td>Dry crops</td>
<td>151.73</td>
</tr>
<tr>
<td>Fallow land</td>
<td>23.36</td>
</tr>
<tr>
<td>Land with Scrub</td>
<td>2.32</td>
</tr>
<tr>
<td>Mining Activities</td>
<td>1.41</td>
</tr>
<tr>
<td>Plantations</td>
<td>164.84</td>
</tr>
<tr>
<td>River</td>
<td>93.11</td>
</tr>
<tr>
<td>Rural</td>
<td>30.12</td>
</tr>
<tr>
<td>Salt affected areas</td>
<td>130.12</td>
</tr>
<tr>
<td>Sandy areas</td>
<td>28.6</td>
</tr>
<tr>
<td>Tanks</td>
<td>129.62</td>
</tr>
<tr>
<td>Towns</td>
<td>24.04</td>
</tr>
<tr>
<td>Water logged areas</td>
<td>7.75</td>
</tr>
<tr>
<td>Wet Crops</td>
<td>180.2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>970.00</strong></td>
</tr>
</tbody>
</table>

Near the rain fed tanks paddy cultivation is practiced, as one time crop where ever, surface water is available. Paddy, sugarcane and oil seeds cultivation are the main crops grown during rainy season. Maize, cotton and groundnuts are dry crops cultivated in the rest of the period. The habitants mainly cultivate palm along the coast and engaged in handicrafts and cottage industries.

Rural settlements and town settlements are noticed along the banks of the rivers and tanks. Salt affected landforms exist in north and east with an areal extent of about 130.12 Km². There are two mines, one in central and the other in southeastern region. Fallow lands literally known as wasteland are seen as isolated pockets in the entire study area with an areal extent of 23.36 Km². The aquaculture has been practiced along the coastal tract, which is one of the major occupations of the coastal habitants. The annual marine fish production is about 10,000 tonnes and
dry fishes are exported to other countries, which earns revenue to the public.

2.5.4 Drainage

Drainage is defined as channeling of surface flow into the sub surface formations. The flow of the sub surface water in a terrain depends on the drainage pattern. Drainage map of the study area has been prepared using satellite imagery (Fig.2.9). River Gundar covers an area of 93.11 Km² from its entry in to the study area and before it confluences with the Bay of Bengal. It is an ephemeral type of river, which has the surfacc flow only during the monsoon period. It drains major part of this area. Streams like Kanal Odai, Gridhammal River, which are tributaries of River Gundar, drains along the northeastern and central portion of the area. Terku River drains along the northern part in the hard crystalline terrain. River Gundar splits into two near Kamudhi and the one flows towards the southeast is called Raghunatha Cauvery. Vembar River and Kadukusani Odai are the other tributaries of River Gundar in south. A large number of naturally formed rain fed tanks exist in this region and they are filled with rainwater during monsoon season. These rain fed tanks cater the need of domestic and agricultural purpose. A very few rain fed tanks smaller in size are fenced, protected and preserved for drinking purpose only. These are locally called "Ooranis.

2.5.5 Soil

The fertility of any place can be assessed by the analysis of the soil present in that area. Certain crops grow only in the special type of soil. A detail soil map of the study area has been prepared (Fig.2.10) from IRS
imagery and validated with recent regional soil map. The soils of this region have been classified as black, red ferruginous and arenaceous. Black soil is noticed in central region (Kamudhi). Red ferruginous soils are confined to a few pockets around Periya Kattangudi, south of Thiruchuli and Abiramam. The sandy soils are present all along the coast. Most of the area is characterized by the alluvial soil with clay. The coastal sandy soil is suitable for coconut farming and a number of palm groves exist along these tracts. The black soil is suitable for cultivation of maize, chilly, cotton and pulse. A few brick kilns are situated in clay region near Mudukulathur. The ferruginous soils and laterite covers are not suitable cultivation. The poor fertility of soil and quality of groundwater as well as insitu salinity in marine sediments have restricted the cropping pattern and its areal extent.

2.6 GROUNDWATER POTENTIAL ASSESSMENT USING GIS

In the present study, overlay method is used in the identification of high groundwater potential zones. The classification is made based on the factors and themes that are capable of holding water. The most significant and least significant are decided based on the Delphi concept. Various authors used this method for integrating different layers (Linda Aller et al., 1987, Krishnamurthy et al., 1996 and Vaithiyanathan et al., 2001). The Delphi approach is one, in which various themes are assigned rank and weightage with respect to their merit. This methodology is adopted in the present study to identify high potential zones using ARC / INFO and Arc / View software.

The most significant and favourable property in the above themes has been assigned maximum rank 4 while less favourable is allotted
rank 1. The procedure above is achieved through a vector overlay analysis by selecting appropriate thematic layers, integrating with one another, using the weighted aggregation method. As per this method, the total weights of the final integrated polygons are derived as a product of the weights assigned to the different layers based on suitability (ESRI, 1988 & 1989).

2.6.1 Integrating Themes for Groundwater Potential

The various themes considered for the present integration study are Geology,Geomorphology, lineaments and palaeochannels and Drainage (Fig. 2.10a). The themes selected and the rank assigned for identifying groundwater potential is shown in table – 2.3.

The integration of geology and geomorphology have been done using the command UNION to obtain the Union 1 and same procedure is repeated for the lineaments, palaeochannels and drainage to obtain Union 2. The final output Union 3 (Fig. 2.11) is obtained integration of Union 1 and Union 2 using the UNION command. This Union 3 theme is subjected to statistical analysis and the study area is classified into three zones namely 1. High, 2. Moderate and 3. Low. Using this methodology, Sridhar (2001) has classified upper Kodavanar basin, Tamil Nadu and identified groundwater potential zones.
Fig. 2.10 a Integration of Various Themes

- Union 3
- Union 1
  - Geology
  - Geomorphology
- Union 2
  - Lineament
  - Palaeochannel
  - Drainage
<table>
<thead>
<tr>
<th>Sl.No</th>
<th>Themes</th>
<th>Features</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Geology</td>
<td>Sandstone</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Alluvium</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Laterite</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hornblende biotite gneiss</td>
<td>1</td>
</tr>
<tr>
<td>2.</td>
<td>Geomorphology</td>
<td>Pediment, Buried Pediment &amp; Flood Plain</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sedimentary highland</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coastal Plain &amp; Sedimentary Plain</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Upland</td>
<td>1</td>
</tr>
<tr>
<td>3.</td>
<td>Lineament and Palaeochannel</td>
<td>Lineament</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fault</td>
<td>2</td>
</tr>
<tr>
<td>4.</td>
<td>Drainage</td>
<td>Tank</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>River</td>
<td>3</td>
</tr>
</tbody>
</table>

2.6.2 Significance of Integration of Various Themes

From the final output map (Fig. 2.11), it is inferred that the entire northern region of the study area has been identified as Low Potential zone. This area lies at higher altitude with basement exposure. Groundwater is stored only in weathered portions. Surface runoff is very high due to gradient.

Moderate potential zone occurs in the central and southeastern regions of the study area. This zone exists between the elevated and plain lands. Fresh water occurs in this zone (vide Chapter – IV).

High potential zone exists along the southwestern part of the study area. The flow direction of the groundwater is initially at NW – SE direction and changes to NS direction along the southern portion. This
zone falls near the coast and area of discharge. The groundwater flow
direction and discharge zone have been confirmed by isotope studies
(vide sub title 4.14).

From the above investigations, it is inferred that the landforms in
higher elevation acts as a zone of recharge and poor zone of potential
where as, the southern plain landforms act as a zone of discharge and
high potential groundwater zone. Robert et al., (1997) after a similar
study in British Columbia, stated that hillside sites or elevated sites are
always act as recharge sites while seepage sites are discharge sites.

2.7 Significance

The northern region is covered by crystalline basement of
Archaean, mostly of hornblende biotite gneiss overlain by Cuddalore
sand stones unconformally. These sand stones are exposed in north,
northeastern and western part of this area. The study area is mostly
covered by recent alluviums, which occur in north along the river course,
in central and southern region. Kankar and laterite occur as patches.
Marine and fluvio-marine formations exist along the coast.

From the geological cross sections, it is inferred that the depth to
the basement is shallow in northern region and increases towards the
coast. Clay and sand layer exist alternately, of which the thickness of the
clay formation increases towards south. Sand layer occurring above this
clay formation forms a shallow aquifer.
Geomorphology map indicates presence of pediment and buried pediment and are capable of storing groundwater, which may form a groundwater potential zone. Sedimentary high lands that exist in the north, northeastern and western part forms recharging zones of this area.

From the lineament and palaeochannel map of this area, the existence of palaeochannels and lineaments that favour the groundwater movement and storage have been identified near Mudukulathur and southern coastal region. The GIS integration also confirms the above statement.