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जल संसाधन, नदी विकास और गंगा संरक्षण मंत्रालय

भारत सरकार

Central Ground Water Board

Ministry of Water Resources, River Development and Ganga Rejuvenation

Government of India

Report

on

AQUIFER MAPPING AND GROUND WATER MANAGEMENT

Chennai Aquifer System, Tamil Nadu

दक्षिण पूर्वी तटीय क्षेत्र, चेन्नई

South Eastern Coastal Region, Chennai

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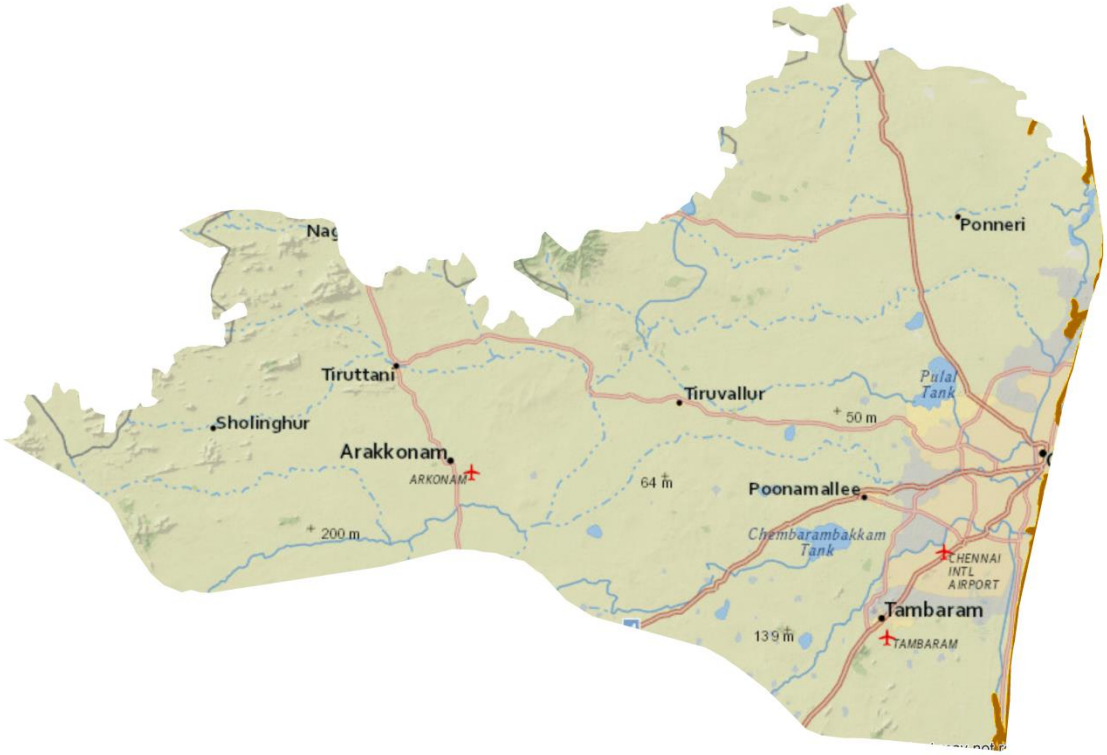
REPORT ON
AQUIFER MAPPING AND AQUIFER MANAGEMENT PLAN FOR THE CHENNAI AQUIFER SYSTEM, TAMILNADU



Government of India
Ministry of Water Resources, River Development & Ganga Rejuvenation
Central Ground Water Board, South Eastern Coastal Region
Chennai

March 2017

Foreword

Groundwater is the major source of freshwater that caters the demand of ever growing domestic, agricultural and industrial sectors of the country. This renewable resource has been indiscriminately exploited in some parts of the country by several users as it is easily available and reliable. Intensive and unregulated groundwater pumping in many areas has caused rapid and widespread groundwater decline. Out of 6607 ground water assessment units (Blocks/ mandals / taluks/ firkas etc.), 1071 units are over-exploited and 914 units are critical. These unitshave withdrawal of ground water is more than the recharge (over exploited) and more 90% of recharge (Critical).

Central Ground Water Board (CGWB) has taken up largest Aquifer mapping endeavour in the world, targeting total mapable area of country ~ 23.25 lakh sq. km with a vertical extent of 300 m in soft rock area and 200 m in hard rock area. The extent of aquifer, their potential, resource availability, chemical quality, its sustainable management options will be addressed by National Aquifer Mapping (NAQUIM). The NAQUIM programme will also facilitate participatory management of ground water to provide long term sustenance for the benefit of farmers. Currently, focus is on ground water stressed areas of eight states comprising 5.25 lakh sq.km viz. Tamil Nadu, Haryana, Punjab, Rajasthan, Gujarat, Andhra Pradesh, Telangana, Karnataka and Bundelkhand region.

South Eastern Coastal Region, Central Groundwater Board, Chennai Under NAQUIM has been envisaged with the Mapping of an area of 70,102 sq.km during 2012-17 (XII five year plan) in Tamil Nadu and UT of Puducherry. This report deals with the Aquifer mapping studies carried out in water stressed Chennai aquifer system covering an area of 6424 sq .km with 6288 sq.km as mappable area. The basin comprises of water stressed districts of Tiruvallur, Chennai and parts of Kancheepuram and Vellore with 109 firkas. 38 firkas are Over Exploited and critical and is mainly dependent on groundwater (85%) for its drinking water needs. The major issues in the basin include declining groundwater levels, sustainability of wells, low yielding aquifers, threat of seawater intrusion, groundwater mining for urban city and groundwater concentration due to industrial clusters and landfills. Aquifer units have been deciphered firkas wise and regions of high yielding zone and low yielding have been demarcated for both soft and hard rock formation in the Chennai aquifer system. In hard rock regions two aquifer Units namely weathered and Aquifer Unit –II is the fractured/Jointed zone. In order to arrest the declining groundwater levels and increase the sustainability of wells groundwater management plans in supply and demand side have been formulated firka wise.

I hope this report will be useful for the district administrators, water managers, stakeholders including farmers in knowing the aquifer and managing it resources effectively in the Chennai aquifer system.

A.Subburaj
Head of Office

EXECUTIVE SUMMARY

Detailed hydrogeological studies were conducted in the study Chennai Aquifer system region wherein huge existing data pertinent to geology, geophysics, hydrology, hydrochemistry was collected, synthesised and analysed to bring out this report. This report mainly comprises the the lateral and vertical extent of the aquifer with its geometry, aquifer properties of the study area which are considered to be measuring scales for groundwater availability and potentiality. Keeping these parameters in view a sustainable management plan has been suggested through which the groundwater needs can be fulfilled in a rational way.

Area experiences semi-arid climate with mm annual normal rainfall covering 6288 km^2 area in Chennai, Kancheepuram, Tiruvallur and Vellore districts of Tamil Nadu. About 61% of the geographical area is under agricultural activity of which 42% is groundwater irrigation. The main crops irrigated are paddy, sugarcane, groundnut, maize, cotton, ragi and other minor crops are turmeric, vegetables and flowers.

Two main aquifers units exists they constitute, namely 1. weathered zone at the top followed by a discrete anisotropic fractured/fissured zone at the bottom in the western and southern part of the study area. 2. Alluvium in the central and eastern portion underlined compact conglomerates of the Gondwana formation. Groundwater occurs under unconfined condition in the weathered zone & in the alluvial formation and unconfined to semi-confined conditions in the conglomerates and fractured/fissured zone. The predominant water levels are in the range of 5-20 m bgl during pre-monsoon season and 2-10 mbgl during post-monsoon season of 2015. The net annual ground water availability is 1240.75 MCM and the gross ground water draft is 844 MCM and the stage of groundwater development is of 68%.

The major issues in the region are Decline in Ground water Level and low sustainability, threat of Sea water Intrusion, Groundwater Mining for Chennai city, Groundwater Contamination due to Landfill sites, Groundwater Contamination by Industries (Petrochemicals, Tanning & Electro-plating), Urbanisation and huge demand for ground water to cater growing Chennai City Population and Low yielding aquifer units. The Chennai city requires 1220 MLD of water for drinking purposes and state government is able to supply 835 to 875 MLD of water, which leaves a huge gap between the demand and supply.

In hard rock regions aquifer systems can be conceptualized as weathered zone down to ~30m with average thickness of 18m and fractured zone between ~190 m bgl. The weathered zone is disintegrated from the bed rock (upper part–saprolite zone) and partially/semi weathered in the lower part (sap rock zone) with transmissivity varying between 4–32.3 m^2/day and specific yield of 0.5 - 3%. The fractured zone is fractured gneiss or Charnockite which occur in limited extent, associated sometime with quartz vein. The average transmissivity of this zone varies between 3.5–45.2 m^2/day and storativity varies from 0.002 to 0.01. In alluvial regions the first aquifer unit comprising of sand, gravel has thickness ranging from 5 to 50 m with yields ranging from 68 to 140 m^3/hr and transmissivity values ranging from 1271 -4180 m^2/day. Gondwana formation comprising of compact conglomerates underlie the alluvial formation and have poor yields ranging from 2 to 27 m^3/hr with transmissivity values ranging from 2.2 to 143.2 m^2/day.

Fast growing urban agglomerations shares the groundwater which otherwise is being used for irrigation purpose resulting in either shortage for irrigation needs or creates excessive draft to meet the both demands in groundwater potential areas. The study formulates management strategies for supply side as well as demand side. The supply side measures include construction of artificial recharge structures of 23 Check dams, 166 nala bands, 372 recharge shafts in addition to the 273 ponds earmarked for rejuvenation with recharge shafts in all the 38 OE 7 Critical firkas of the basin. The estimated cost for construction of these structures is to be Rs. 56.4 Crores. The estimated recharge to groundwater system through these structures will be in the order of 54 MCM with an additional area of Paddy : 3375 ha or Sugarcane : 2700 ha (or) Banana : 5400 ha (or) Irrigated Dry crops : 10189 ha. Demand side management is also recommended by change in irrigation pattern from flooding method to Ridge & furrow for paddy and flooding to drip for sugarcane and banana crops. This intervention would save 289.12 mcm of water annually. By carrying out both supply and demand side interventions the stage of groundwater development would be lowered from 68 to 45%.

The existing regulatory measures may be modified suitably for optimal utilization of groundwater as well as for sustainable development of rural agricultural based economy. To achieve this goal opinion pool has to be obtained from more user groups and valid suggestions of may be incorporated in the regulatory acts.

REPORT ON
AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUNDWATER RESOURCES IN CHENNAI AQUIFER SYSTEM

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AQUIFER MAPPING FOR SUSTAINABLE MANAGEMENT OF GROUNDWATER RESOURCES IN CHENNAI AQUIFER SYSTEM, TAMIL NADU

Contents

AQUIFER MAPPING AND MANAGEMENT PLAN FOR CHENNAI AQUIFER SYSTEM, TAMIL NADU

1.0. INTRODUCTION

National Project on Aquifer Mapping (NAQUIM) initiated by Ministry of Water Resources, River Development and Ganga Rejuvenation, Government of India with a vision to identity and map the aquifers at the micro level with their characteristics, to quantify the available groundwater resources, propose plans appropriate to the scale of demand and institutional arrangements for participatory management in order to formulate a viable strategy for the sustainable development and management of the precious resource which is subjected to depletion and contamination due to indiscriminate development in the recent past.

Ground water is being increasingly recognized as a dependable source of supply to meet the demands of domestic, irrigation and industrial sectors of the country. The development activities over the years have adversely affected the ground water regime in many parts of the country. Hence, there is a need for scientific planning in development of ground water under different hydrogeological situations and to evolve effective management practices with involvement of community for better ground water governance.

Aquifer Mapping has been taken up in Chennai Aquifer system basin in a view to formulate strategies for sustainable management plan for the aquifer system in accordance with the nature of the aquifer, the stress on the groundwater resource and prevailing groundwater quality which will help in drinking water security and improved irrigation facility. It will also result in better management of vulnerable areas.

1.1.Objective:

The objectives of the aquifer mapping project in Chennai aquifer system can broadly be stated as

1. To define the aquifer geometry, type of aquifers and their lateral and vertical extent
2. To determine the ground water regime scenario
3. To determine the hydrogeochemical characteristics of the aquifer units
4. 2D and 3-D disposition of the aquifer units.
5. To estimate the availability of groundwater resouces in the aquifer system
6. To develop an sustainable groundwater management plan for the aquifer system.

1.2. Scope of the Study:

The important aspect of the aquifer mapping programme is the synthesis of the large volume of data already generated during specific studies carried out by Central Ground Water Board and various Government organizations with a new data set generated that broadly describe the aquifer system. The available generated data are assembled, analysed, examined, synthesized and interpreted from available sources. These sources are predominantly non-computerized data, which is to be converted into computer based GIS data sets.

Data gaps have been identified after proper synthesis and analysis of the available data collected from different state organisations like TWAD Board, PWD, Agricultural Engineering Department. In order to bridge the data gap, data generation programme has been formulated in an organised way in the basin. Exploration work has been carriedout in different segments of the regions and aquifer parameters have been estimated. Groundwater monitoring regime has been strengthened by establishing additional monitoring wells. 2D and 3D sections have been prepared twice, one prior to the generation of data based on the data collected, assembled and synthesized through different sources and two, after generation of data at identified gaps. The latter prepared maps are of more realistic as the data points are more closure.

1.2a Issues

1. Decline in Ground water Level and low sustainability. (Figure.1)
2. Threat of Sea water Intrusion.
3. Groundwater Mining for Chennai city.
4. Groundwater Contamination due to Landfill sites
5. Groundwater Contamination by Industries (Petrochemicals, Tanning & Electro-plating)
6. Urbanisation and huge demand for ground water to cater growing Chennai City Population.
7. Low yielding aquifer units.

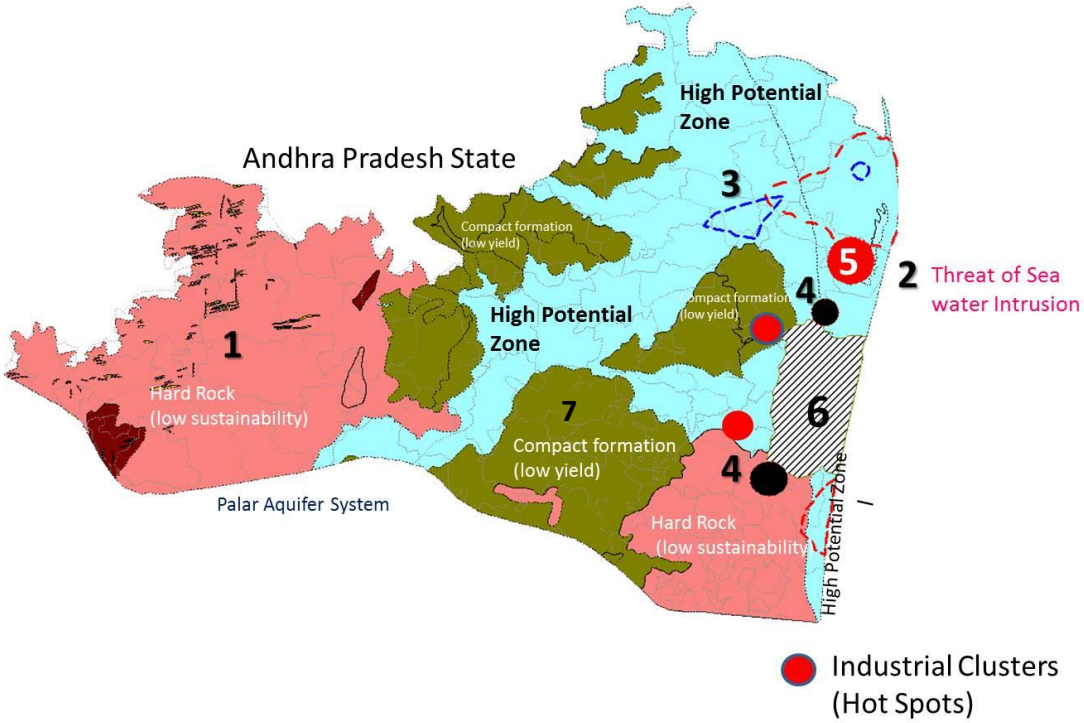


Figure.1. Issues pertaining to the Chennai Aquifer system

1.3. Approach & Methodology:

Integrated multi-disciplinary approach involving geological, geophysical, hydrological and hydrogeological and hydrogeochemical components was taken up in 1:50000 scale to meet the objectives of study. Geological map of the basin has been generated based on the GSI maps, geophysical data has been generated through vertical electrical soundings and geoelectrical layers with different resistivities have been interpreted in corroboration with the litho stratigraphy of the observation wells and exploratory wells down to depths of 200m and 300 m bgl for hard rock & soft rock respectively. Hydrological and Hydrometerological data has been collected from state PWD and IMD departments. Drainage, Soil and Geomorphology of the subbasin was prepared based on the IRS –IC data, obtained from Institute of Remote Sensing, Anna University, Chennai.

Based on the data gap analysis data generation process has been scheduled through establishing key observation wells, pinpointing exploratory sites for drilling through in-house and outsourcing, collecting geochemical samples in order to study groundwater regime, geometry of the aquifer and aquifer parameters, and quality of the groundwater respectively. Groundwater recharge and draft have been computed through different methods and resources of the basin estimated through groundwater balance method.

Based on the above studies Management strategies both on the supply side through augmentation of groundwater through artificial recharge and water conservation and on demand side through change in irrigation pattern have been formulated for sustainable management of the groundwater resource.

1.4. Study area:

The Chennai aquifer system covering an area of 6629 sq.km comprises of 341 sq.km of hilly area and 6288 sq.km of mappable area is situated between latitudes 12°40'N and 13°40'N and longitudes 79°10'E and 80°25'E at the north and north east corner of Tamilnadu. It is bounded by Andhra Pradesh state in the north; Palar River aquifer system in the west and south and the Bay of Bengal sea on the east. Araniyar (covers 763 km²), Kosathalayar (covers 3.240 km²), Cooum (682 km²) and Adyar (857 km²) are the four rivers of this basin region. This aquifer system covers partly or fully 26 blocks of Tiruthani, Thiruvallur, Saidapet, Tambaram, Ponneri, Sriperumbudur, Arakonam, and Walajapet taluks of Thiruvallore, Kanjeepuram, Chennai and Vellore districts. There are 109 firkas out of which 38 are over exploited/critical firkas (Table.1). The major part of the basin area comes under Thiruvallore and Chennai districts

(fully covered) and only a few regions of Vellore and Kanjeepuram districts are covered. Of the four rivers, the Adyar River carries the floodwater and drainage of Chennai city and its environs. It does not have any direct irrigation and carries only the flood discharge during the northeast monsoon period for few days. The Coovum River serves as drainage and sewerage carrier within the Chennai city limit. The administrative map of the Chennai aquifer system is presented as figure.2

Table.1 Districts and Firkas of the Chennai aquifer system

Sl. No	District	Area Sq Km	No. of Firkas	No. of OE and Critical Firkas
1	Chennai	179	20	20
2	Kancheepuram	1914	33	4
3	Tiruvallur	3538	46	12
4	Vellore	998	10	2
Total		6629	109	38

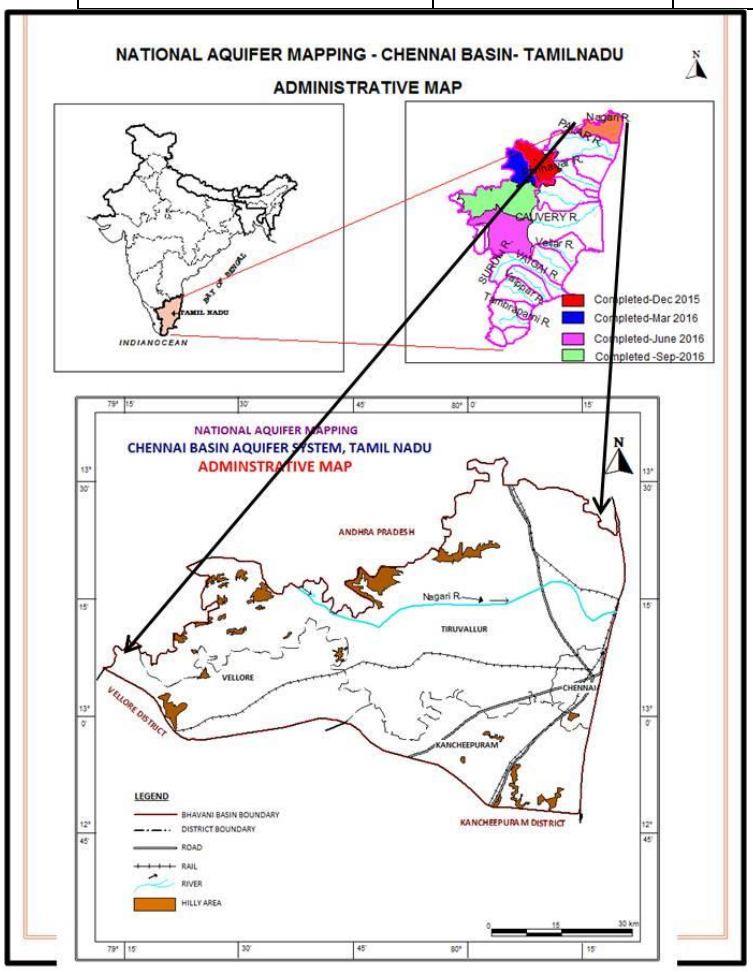


Figure.2 Administrative setup of the Chennai aquifer system

1.6. Data adequacy

Exploratory well data is available for 274 wells drilled by CGWB (177 nos) and State Departments (97 nos). Water level (211 nos) and Water Quality monitoring data (148 nos) data was available for a long period i.e., more than ten years. 124 nos of Vertical electrical sounding data was available. Cropping pattern and Soil data has been collected from Agricultural and Statistics Department. After plotting the available historical data on 1:50,000 scale maps, data gaps have been identified and data generation process has taken up in those gap areas to complete the Aquifer map on the desired resolution of 1:50,000 toposheets. A proposal for construction of ____wells through outsourcing has been identified to complete the gaps in the data.

1.9. Physiography and Drainage

The term physiography deals with the actual existing in-situ conditions of the land, depending upon the structures, formational changes and available natural agencies such as Hydrogiene and Epigiene agents. Physiographically the Chennai aquifer system region comprises of interdependent river basin of Araniar, Kosathalayar, Cooum and Adyar (Figure.3) all rivers mostly flow from west to east with a man made artificial Buckingham canal runs from north to south. The river Araniar and Kosathalayar originate from Andhra Pradesh whereas the Cooum and Adyar originate from surplus courses of Cooum tank in Thiruvallore Taluk and Chembarambakkam Tank in Sriperumbudur Taluk. All these four rivers stretching from west to east and confluence with Bay of Bengal in the East.

The length of the river is 200 km.; width varies from 180 to 120 km. The Maximum elevation 1219 m above m.s.l. and minimum elevation is 5 to 15 m above mean sea level. The main tributaries are Nagari River, Araniar, Korathalayar, Cooum, Adyar and Buckingham canal. There are four major reservoirs situated in this basin. They are Poondi (Sathyamoorthy Sagar), Red Hills, Sholavaram and Chembarambakkam. The total command area in Chennai basin is about 1,31,665 hectares and there are 1,304 tanks by which 85,208 ha are irrigated. The storage capacity of the tanks is 410 mcm and the total capacity of the basin is 1069 mcm. The Capital city Chennai, is more or less plain to gentle and the Coastal physiography only occurs.
The maximum and minimum elevation of the Chennai aquifer system is from 595 m a msl in the west to sea level in the east. The nominal topography is generally slopping towards the East and Southeast. The general trend of dipping ranges from West to East. The Hydraulic gradient and the flow lines of ground and surface water are towards east, the sea.

The study area comprises of the major rivers like Araniyar and Korathalayar in the north and the Adyar and Cooum in the south. Apart from these rivers, there is a manmade canal, the Buckingham Canal runs north to south along the eastern narrow coastal strip. There is a large catchment area commanded by the rivers Araniar and Korathalayar, leaving the rest of the rivers such as Adyar and Cooum are having a very small catchment. There is more number of systems and non-system rainfed tanks lies in the study area. These water bodies were very specifically useful in meeting the drinking water needs of the Chennai Metropolitan Area and rarely for irrigation and for industrial uses of many number of industries located around Chennai city and its urban agglomerate.

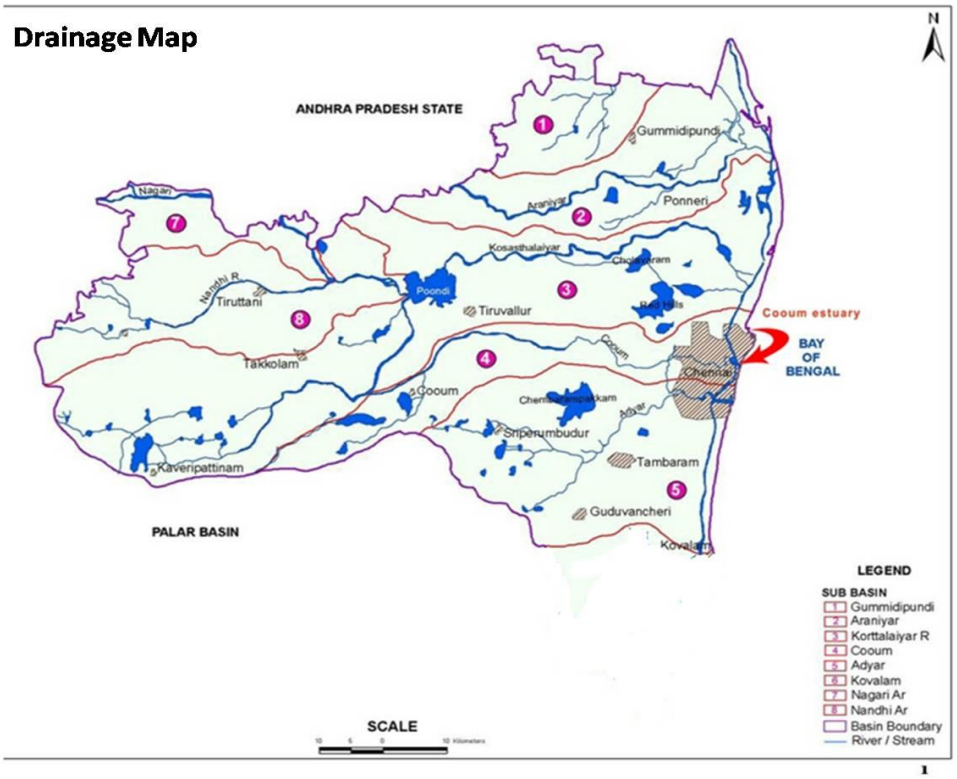


Figure.3 Drainage map of the Chennai aquifer system

1.10. Geomorphology:

The geomorphology of an area is the external appearance of landforms, that gives a reliable picture of the underground strata and its physio-chemical condition. The different formations and the layer confirms and cogent to its geomorphology. Four major geomorphic units can be demarcated hilly regions, plains, urban areas and coastal landforms. The eastern part adjoining to beach and shores covers coastal geomorphic units. The inland topographical units are being described as the piedmont geomorphology.

The coastal landforms include the beaches, beach ridges and beach terraces : The beaches are landforms covered by sand and sandy materials having high porosity and unconsolidated loose formation with voids and spaces. Beach Ridges are elevated sandy tops adjoining the beaches and are good horizons for groundwater presence. The step like projection bordering the sandy terrain and the shoreline are called as beach terraces. These terraces are undulated and according to the forces of the tide and their deposition. These terraces were having a very low ground water gradient that too towards the sea as they are slopping towards them.

Nearly 60% of the region is covered by Plains and is represented in figure.4. These are smooth surface evidenced the erosion. These plains are the inland topography where the terrain sediment such as laterite, limestone and other calcareous sedimentary have been leached and washed away by sedimentation. According to groundwater point of view they are serving poorer ground water storage. The surface of these formations are showing a honeycomb structures and the water level are medium to high from the top surface. These were located

around north of Kosathayar riverbed adjoining Manjankaranai and around. Certain spots were too located as isolated patches in between Araniar and Kosathalayar River.

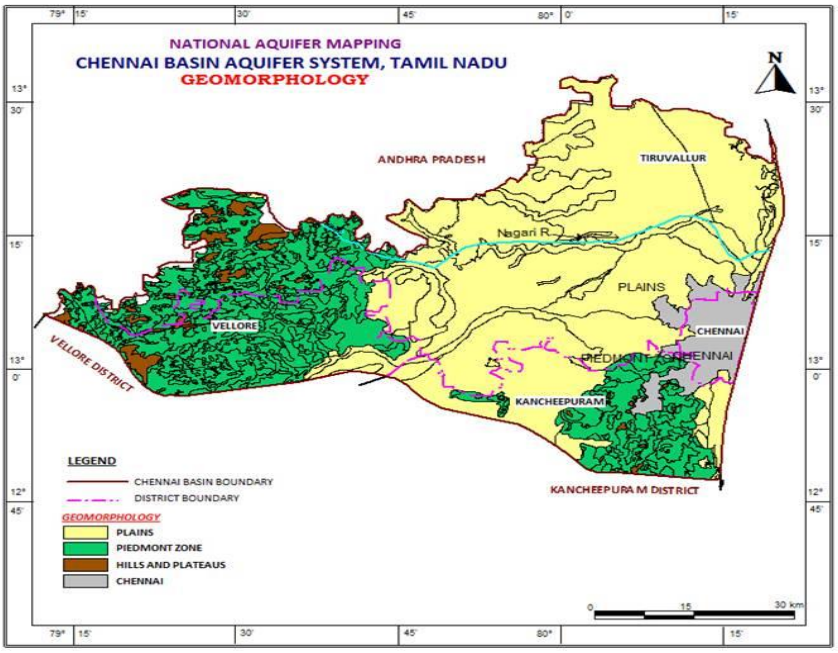


Figure 4. Geomorphology map of the Chennai aquifer system

34% of the region is covered by pediments which include the buried pediments adjoining Araniar, Kosathalayar, Cooum and Adyar Confluences and certain interior parts adjoining these rivers. Deep Pediment, Shallow and buried channels. Flood plains consisting of sand clay are found along the boundaries of Araniar and Kosathalayar rivers. The thickness of the alluvial sand varies from 1 to 7 m and the flood plain itself is found spread over width varying from 0.25 to 5.0 km from the riverbanks. The piedmonts regions constituting of boulders, cobbles, pebbles, grovels, sand, silt and clay of varying lithology. Formed by coalescence of several alluvial fans by streams covering large area at the foothills, with gentle slopes, in humid to sub humid in regions (upper humid to sub humid regions). Figure 5 illustrates the level I classification of geomorphological features of the Chennai aquifer system.

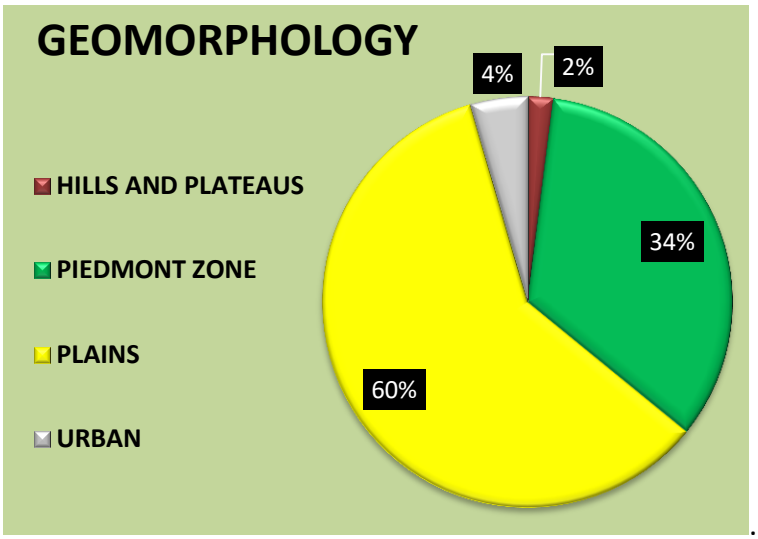


Figure.5 level I classification of geomorphology of the Chennai aquifer system.

1.11. Landuse and Land cover:

Agricultural land occupies nearly 3860 sq.km i.e., 61% of the Chennai aquifer system area and spread throughout the study area. Deciduous forest occupies nearly 357 sq.km (06 %) of the area taking the green area to 67% (Figure 6 & 6a). Water bodies, Waste land and built up/urban area occupies 13, 10 and 10 % respectively.

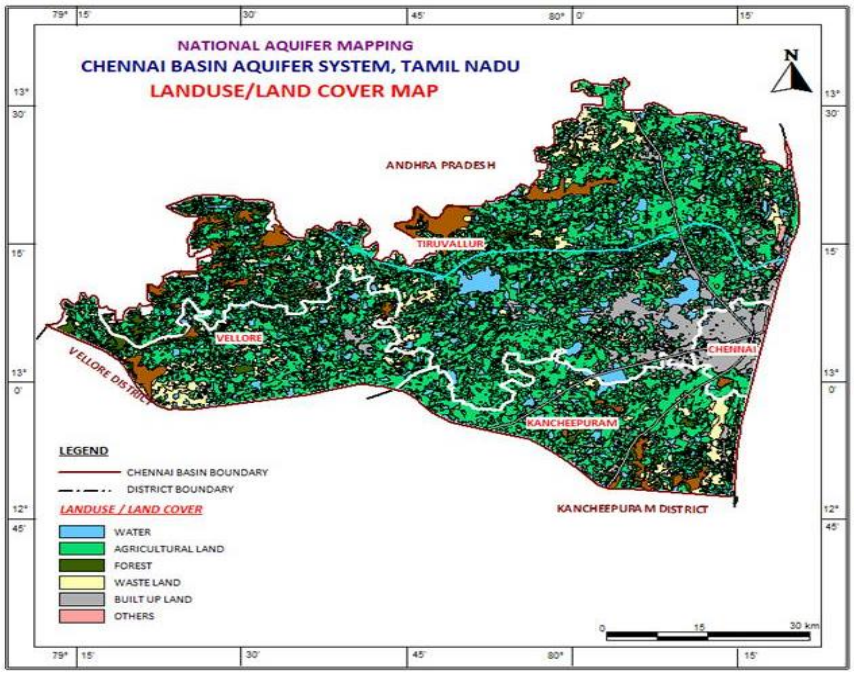


Figure 6. Level 3 Landuse/Land cover map of the Chennai aquifer system

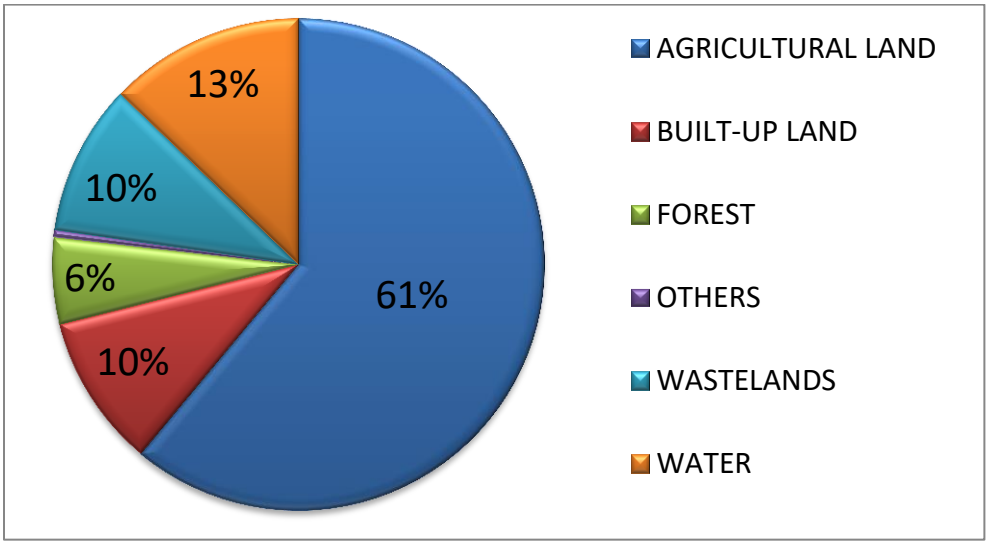


Figure 6a . Level 1 Landuse/Land analysis diagram of the Chennai aquifer system

1.12. Soils:

Soils play a major role in hydrologic control of the infiltrating water. Soils are generally classified by taking their color, texture, fertilities and chemical combinations includes salts, minerals and the solution effect over them. The major soil types in the study area are inceptisols and entisols (Figure.7)

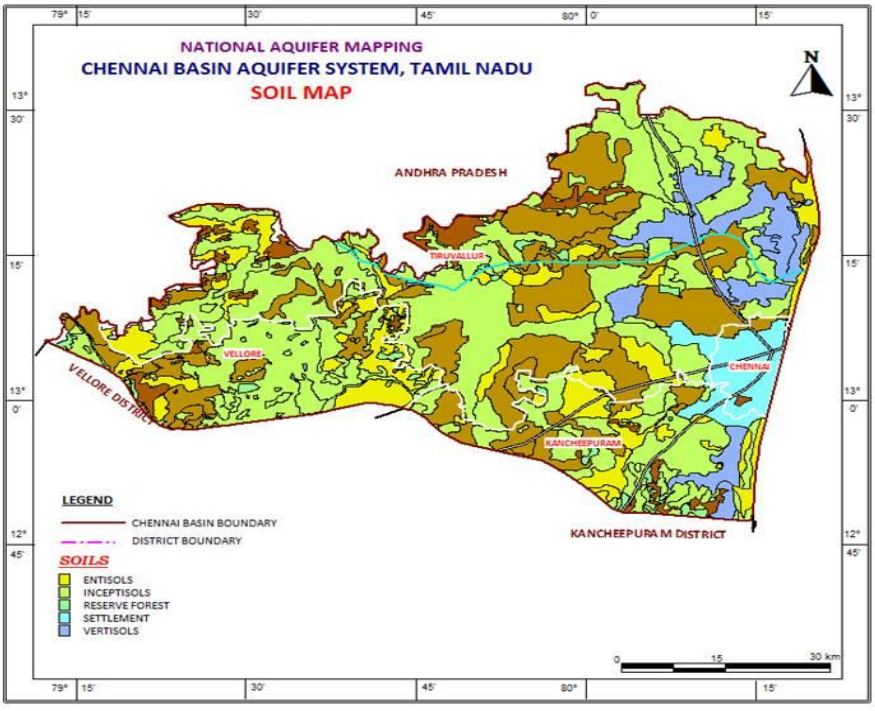


Figure.7 Soil map of Chennai aquifer system

Entisols are alluvial soils comprising sand and sandy materials occurring on the beaches and at the confluence of rivers and by the side of the rivers & channels. Because of their permeability, these soils while being good storehouses of groundwater are not fit for paddy cultivation. Inceptisols are the major soil group found in the study area and consists of the red sandy to brownish clayey soil fragments derived from parent rock and is spread all along the westward side. The Inceptisols are suitable for agricultural hold moderate groundwater reserves. Vertisols are clayey soil with high specific water retention capacity but poor in supporting agriculture. The rate of infiltration varies is very low in this type and ranges from 1 to 3 cm / hr for fine red sandy clay, clayey sand, sandy clay, sand fine to medium, sand medium to coarse and very coarse and gravel and for weathered rock, fractured and jointed rock it varies from 0.2 to 0.5 cm / hr. which normally occur in the study area.

Slope

The slope of any terrain plays a vital role in allowing the infiltration of water into the subsurface system. In regions of gentle slope the runoff will be slow and will have more time for percolation of rainwater, whereas steep slope facilities high runoff allowing less residence time for rainwater to percolate. The DEM map of study area was prepared from the Cartosat DEM of 30 m spatial resolution (Figure.8). The elevation of the Chennai Aquifer system ranges from 595 m a msl in the west to sea level in the east.

1.14. Agriculture:

Agriculture is the main stay of the rural population in the entire study area. The total irrigated area of the Chennai aquifer system area is 1595 sq.km with main water intensive crops irrigated are Paddy, sugarcane and banana covering about 1289 sq.km (Figure.9). The less water intensive crops irrigated are maize, tomato, groundnut, chilly and Jasmine. The other crops include cotton, ragi etc., and other minor crops are turmeric, flowers and vegetables.

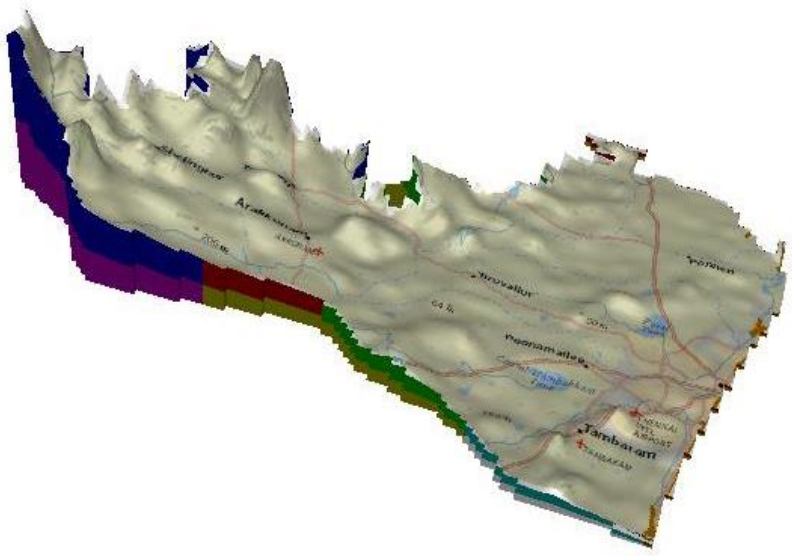


Figure.8 DEM of the Chennai Aquifer system

The total cultivated area is about 3611 sq.km. Table 2 illustates the irrigated crops of the Chennai Aquifer system.

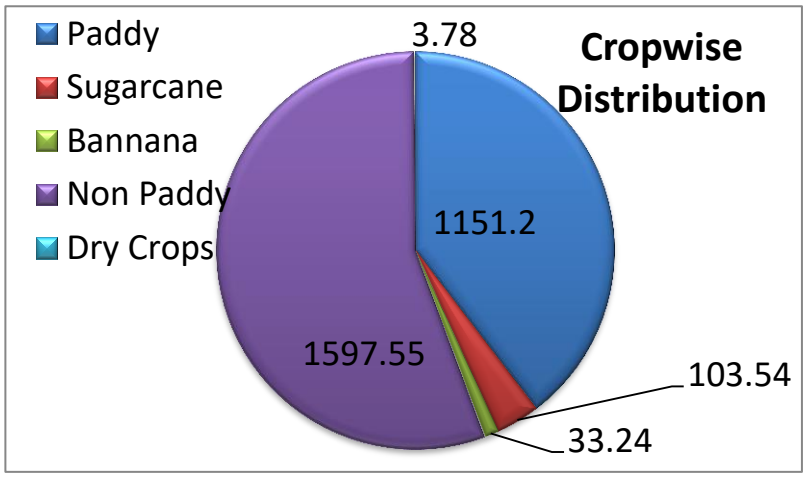


Figure.9 Cropwise distribution in the Chennai aquifer system

Table 2. Irrigated crops of the Chennai Aquifer System

S.No.	Crop	Season	Area Ha.	Percentage of Gross Area Irrigated
1	Paddy	Samba (Aug. Sep. Dec. & Jan.) Navarai (Jan. to Mar.) Sornavari (Apr. to Jul.)	79,390 29,205 23,070	60.30 % 22.20 % 17.50 %

S.No.	Crop	Season	Area Ha.	Percentage of Gross Area Irrigated
2	Groundnut	(Dec. to April)	37,622	19.80 %
3	Sugarcane	(Jan. to Nov.)	10,346	4.50 %
4	Cumbu	(March to June)	5,395	2.80 %
5	Banana	(February to July)	3,345	1.90 %
6	Pulses (Black Gram & Green Gram)	(February to April)	1,279	0.70 %
7	Gingelly	(January to May)	1,039	0.50 %
8	Chillies	(February to July)	1,019	0.50 %

(Dept of Agriculture and Dept of statistics)

1.15.Irrigation:

The total area irrigated under different crops is 1,59,500 ha out of the total geographical area of 6,28,800 ha, which accounts for 44.11%. Paddy is the main water intensive crop in the study area. More than 80% of the total requirement of irrigation is met from groundwater resources. The four major reservoirs present in the study area is allocated for drinking water supply.

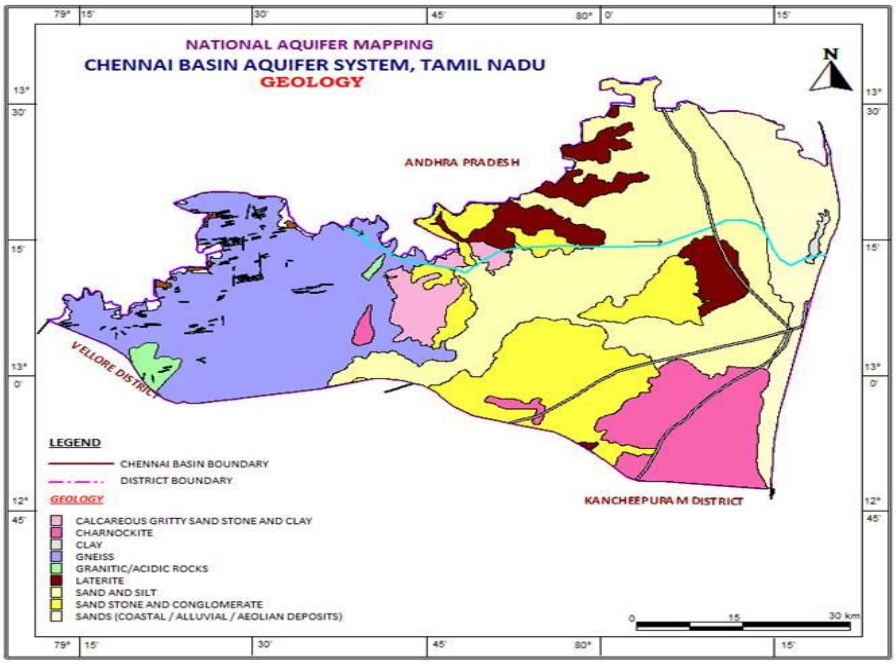
1.16. Geology

Geologically, the Chennai aquifer system comprises of marine, estuarine and fluvial alluvium underlained by Precambrian gneisses and Charnockites. The charnockites form the major rock types and constitute the residual hills around southern part of the study area. Beds of upper Gondwanas are found in and around central and northern portion (Figure.10). These Upper Gondwana formation with type area Sathyavedu comprises of conglomerates, shale, and sandstone, and are covered by a thick cover of laterite. Tertiary sandstone is seen in small patches in the study area ie., in the northwest of Chennai city and upto Satyavedu, and is capped by lateritic soil. Geologic succession of the Chennai aquifer System is presented in Table.3

Precambrian Rocks

The hard rocks include granite, gneissic complex, schist's and chamockites associated with basic and ultra-basic intrusive. The chamockites form the major rock types and constitute the residual hills around Pallavaram, Tambaram and Vandalur. Beds of upper Gondwanas are found in and around Anna Nagar Mogapair, Valasarawakkam, Mambalam, and upto

Sriperumbudur. The western of the Chennai Aquifer system (Figure.10) gneissic rocks are present and they cover an area of 1355 sq.km and Charnockite formation is found in the



eastern part of the study area covering about 537 sq.km.

Figure.10 Geological map of the Chennai Aquifer system

Table 3. Geological succession of the Chennai Aquifer System

S.No	Group	System	Lithology	Groundwater relevance
1.	Quaternary	Recent – Sub-recent	Soils, coastal /river Alluvium (sand & silt), Black Clay, Laterite	Moderate to very good porous aquifer system
2.	Tertiary	Sandstone (Eocene to Pliocene)	Sandstone & and shale	Moderately porous Aquifer.
3.	Mesozoic	Upper Gondwana (Sathyavedu & Sriperumbudur)	Conglomerates, Sandstone and siltstone; Grey shale; Black shale.	Very low Porous aquifer.
4.	Azoic	Archaean	Charnockites, Granites, Gneisses.	Weathered and Fractured Aquifer units.

Gondwanas

The Gondwana series is named after the ancient kingdom of Gonds of Madhya Pradesh. Theses series comprises of massive pile of lacustrine and fluvial deposits. These semi-consolidated formations occurring in the area represent the Upper Gondwanas of Jurassic to Lower Cretaceous rocks and the marine beds of the Cretaceous age. The Upper Gondwana

Sediments consist of two stages viz. the lower Sriperumpudur stage consisting of fluviatile clays, shales and feldspathic sandstones and the Satyavedu stage representing the marine sediments of ferruginous sandstones, conglomerates and boulders. The Sriperumpudur beds occur as patches, with easterly dips at low angles. The age of the Sriperumpudur formation is not certain; but the impressions of the foraminifera and ammonites are suggestive of an age varying from Upper Jurassic to Lower Cretaceous. They are cover about 1297 sq.km area in the Chennai aquifer system.

The Satyavedu stage comprises beds of conglomerate mixed with a few beds of coarse mottled sandstone, beds of clayey sandstones and sandy shales. The conglomerates with a sandy clayey matrix is hard and compact and exposures of it are invariably strewn with shingle, pebbles and boulders. The strata show, in general, a decreasing lateral gradation in the coarseness of component deposits. The conglomerates and boulder beds occur nearer to the crystalline rocks. The total thickness of the formation exceeds 30 m.

Tertiary

The Tertiary beds comprising friable, white, speckled and reddish-brown mottled quartz grit, friable quartzose grits, which are white and brownish in colour becoming whiter at lower depths. Coarse laterite capping changes with depths into reticularly cellular, sandy clay grits. The latter again appear to grade into coarse, friable, mottled grits which become pure white with depth. Similar formations are traced north of the Araniyar river and along the southern bank of the Korattalaiyar river in a line running from the Red Hill lake to the north-northwest. The rocks belonging to this period have been assigned to the Miocene-Pliocene (Cuddalore) series but no fossil evidence of age has been found. It is only on stratigraphical and lithological evidence, that they are separated from the upper Gondwanas.

Quaternary

Boulder Bed: Gondwana series is overlain by the deposits known as Boulder bed in the eastern part of the study area. This bed consists of a mixture of rounded to sub-rounded boulders, cobbles, pebbles and gravel in a clayey sandy matrix and partly compacted. These deposits represent a marginal facies of fluvial deposits worked out from Gondwana conglomerates. Further east, this bed abruptly thins out to a few feet in thickness and as it is overlain by alluvium, forms a good marker of transition to Gondwana deposits.

Laterite: The Tertiary friable sandstone and Gondwana series are commonly capped by scoriaceous and pisolitic laterite. It is noticed around Kannigapuram, Red Hills and Palaiya Erumaimattupalaiyam area. The laterite of Red Hills is of a conglomeratic type comprising mainly fragments of sub-rounded quartz bound by cindered ferruginous cement. Its thickness ranges from 1.50 to 6.5 m and it occurs in the central portion of the study area with spatial distribution of around 322 sq.km

Alluvium

The youngest formations in the area are the alluvium, which was deposited on the worn-down and eroded surface of Tertiary and Gondwana rocks by the major rivers covers an area of 2036 sq.km spatially. It is noted that the alluvial plains in the eastern part of the area, entirely spans the lower reaches of Araniyar and Korattalaiyar and branches off into two separate plains farther east. A cross-section along the west-east direction near the Panjetty-Minjur area is represented in figure. The alluvium consists of gravel, fine to coarse sand, clay and sandy clay of various shades of grey and brown. Commonly, the different types are

Intercalated (or) dovetailed in the form of lenses and pockets which point out the erratic geometry of the deposition, caused by the migration and varying flow velocities of old rivers. Exploratory drilling shows that the thickness of these deposits increase progressively in an easterly direction towards the coast line east of Minjur, where it is about 50-60 m thick. The wind deposited sand, in the form of irregular, low flat dunes ranging in width from less than 0.1 km to about a kilometer occur all along the coast, except where they are interrupted by the river outlets. The most striking dunes are near Pulicat, where they have grown by wind action into irregular mounds of 12 to 15 m high.

2. Data Collection and Generation.

Periodical data pertaining to groundwater levels, quality, pumping tests and slug tests were collected during aquifer mapping studies apart from water sample collection to assess the groundwater quality. In addition Geophysical data has been generated through conducting Geo electrical soundings after evaluation of data gap analysis.

2.1. Hydrogeological data:

The periodical monitoring of ground water level implies the groundwater recharge and discharge (natural and manmade) occurring in the aquifer systems. It also reveals that the interaction between surface and sub-surface water systems. In Chennai Aquifer system area, 211 no's of groundwater monitoring wells which included 96 CGWB monitoring wells, 90 State department wells and 25 piezometers of CGWB (12 shallow and 13 deep) were monitored periodically. To fill data gap in the basin, 141 additional wells were established and monitored periodically during the pre and post monsoon period during the aquifer mapping study. This was useful to record the temporal and special changes in aquifer system. The locations of monitoring wells are presented as Figure .11.

Pumping test data of 41 bore wells was collected and analysed for the the aquifer parameters and 5 wells wherein long duration pumping tests were carried out for determination of specific yield were also analysed and the results are tabulated in table No.4.

2.2. Hydro chemical data:

The groundwater quality of the Chennai aquifer system was studied by collecting water samples from dug well and bore well. Groundwater samples were collected for 289 locations wherein long term record was available only for 148 nos. The sample locations in the Chennai aquifer system is presented in Figure.12. Ground water quality data has been collected from TWAD, Govt.of Tamilnadu and SG&SWRDC, PWD in respect of 489 locations.

Table.4. Results of the pumping test analysis.

Location	Thickness of the aquifer	Type of the aquifer	Type of Formation	Transmi-ssivity	Storage Coefficient/ Sp.yield	Remarks
	m			m^2/d		
Attipattu	26.2	SC/C	SR	2483.855	1.5×10^{-4}	UNDP studies
NE of minjur	31.5	SC/C	SR	2794.337	1.75×10^{-4}	UNDP studies

Location	Thickness of the aquifer m	Type of the aquifer	Type of Formation	Transmi-ssivity m^2/d	Storage Coefficient/ Sp.yield	Remarks
Vallur	12.5	SC/C	SR	807.2529	1.85×10^{-3}	UNDP studies
W of Minjur	11.5	SC/C	SR	1987.084	1.0×10^{-4}	UNDP studies
E of Ponneri	4.3	SC/C	SR	149.0313	-	UNDP studies
E of Ponneri	20.0	SC/C	SR	1117.735	2.1×10^{-4}	UNDP studies
Kattur	13.1	SC/C	SR	894.1878	3.1×10^{-3}	UNDP studies
Duranallur	15.7	SC/C	SR	1018.381	6.2×10^{-4}	UNDP studies
Panjetty	35.8	SC/C	SR	3974.168	2.8×10^{-3}	UNDP studies
Ponneri	9.0	UNC	SR	28	0.07	HP-PDS studies
Minjur	9.0	UNC	SR	1328	0.20	HP-PDS studies
Kannigaipair	9.0	UNC	SR	63.6	0.14	HP-PDS studies
Velliyur	12.0	UNC	SR	615	0.15	HP-PDS studies
Kadambattur	12.0	UNC	SR	2.38	0.01	HP-PDS studies
Yellareddi kandigai	15.0	SC	SR	3924	1.2×10^{-3}	CGWB
Panjetti	26.0	SC	SR	2217	7.55×10^{-4}	CGWB
Neidavoyal	10	UNC	SR	2115.0	-	CGWB
Parikkipattu	22	UNC	SR	763	-	CGWB
Velapakkam	12	SC	SR	4180	-	CGWB
Alamadhi	41	C	SR	1.16	-	CGWB
Puduvoyal	76	C	SR	6.94	-	CGWB
Verapuram	-	C	SR	5.90	-	CGWB
Avadi	70	C	SR	21.81	-	CGWB
Chengadu	12	SC/C	SR	103	5.67×10^{-2}	CGWB
Arcot Kuppam	5 fractures	UNC/SC	HR	45.88	8.6×10^{-3}	CGWB
Athimanjarpet	2 Fractures	UNC	HR	3.57	-	CGWB
K.K.Nagar	2 Fractures	UNC	HR	5.66	-	CGWB
Kilpauk	19.0	SC	SR	871	4.5×10^{-3}	CGWB
Koyambedu	21.0	SC	SR	84.93	1.2×10^{-3}	CGWB
Thiruman-Galam	52	C	SR	135	1.9×10^{-4}	CGWB
Ammur	2 Fractures	UNC	HR	78.3	-	CGWB
Vallimalai	1 Fractures	UNC	HR	1.92	1.59×10^{-4}	CGWB

Location	Thickness of the aquifer m	Type of the aquifer	Type of Formation	Transmi-ssivity m^2/d	Storage Coefficient/ Sp.yield	Remarks
Guttakandur	3 Fractures	UNC/SC	HR	66.0		CGWB
Appukal	3 Fractures	UNC/SC	HR	18	-	CGWB
Odugattur	2 Fractures	UNC/SC	HR	31	-	CGWB
Kalliyur	5 fractures	UNC/SC	HR	134	-	CGWB
Andiappanur	5 Fractures	UNC/SC	HR	29	9.2×10^{-2}	CGWB
Thoplagunda	5 Fractures	UNC/SC	HR	29.2	5.7×10^{-5}	CGWB
Punganur	3 Fractures	UNC/SC	HR	21.4	1.87×10^{-3}	CGWB

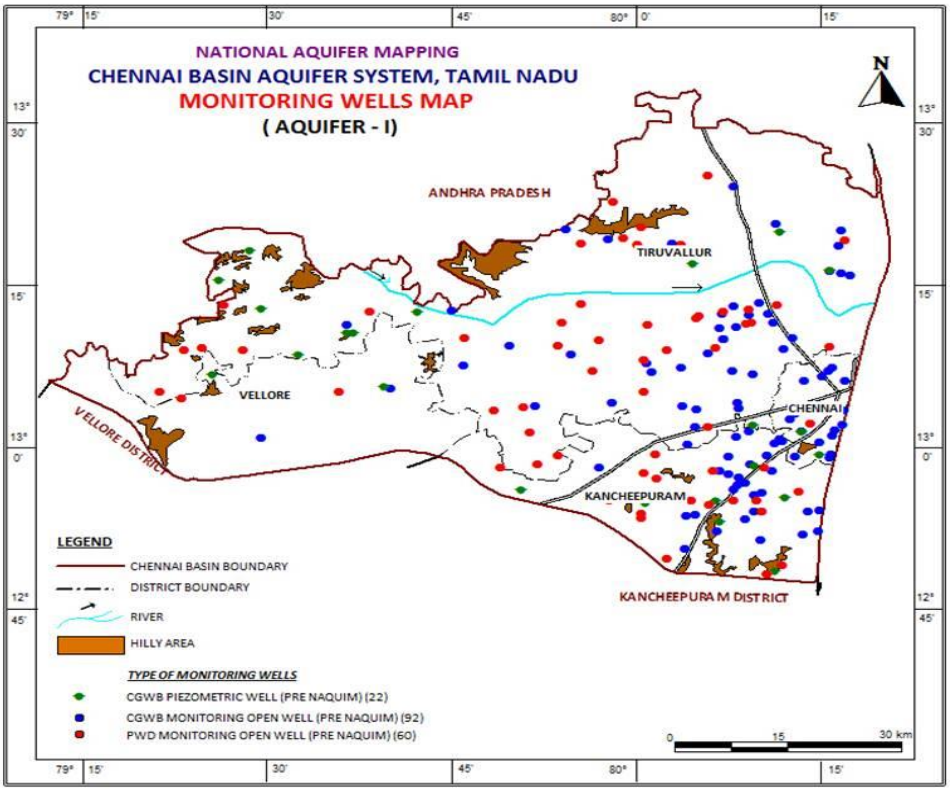


Figure.11 Location of Groundwater Monitoring Wells

2.3. Geophysical data:

The geophysical survey was conducted in the study area consisting of Vertical Electrical Soundings (VES) by employing Schlumberger configuration with maximum half current electrode separation of 300m. The objective of the study area is to decipher the sub surface conditions such as weathered and fractured layer resistivity and thicknesses and massive formations up to the depth of 200 m. A total number of 124 VES were carried out and geo electric layers inferred through interpretation of the results obtained. The locations of the VES are presented in the following **Figure 13**.

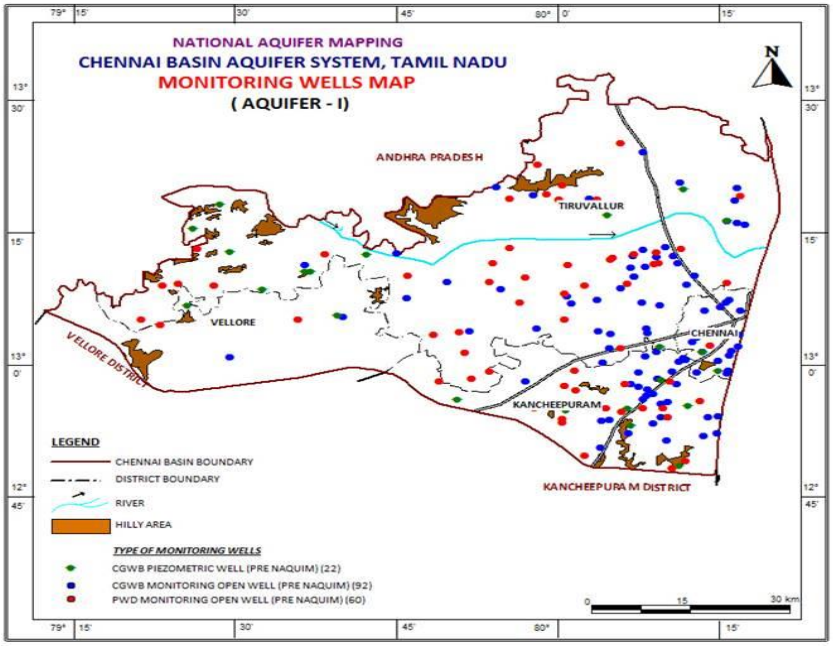


Figure 12 Location of Groundwater quality Monitoring Wells

2.4 Groundwater Exploration data:

Data of 274 Nos of exploratory wells were drilled in the Chennai aquifer system (177nos CGWB and 97nos State department wells) prior to National Aquifer Mapping project was compiled and analysed (Figure.14). These wells were plotted on the 1:50,000 scale topographical map and as per the NAQUIM guidelines for the hard rock & soft rocks, data requirements were identified on the plotted topographical map. Based on the data requirements, 23 nos of exploratory wells have been recommended for drilling through outsourcing activity as part of the data generation. The data such as lithology, fracture depth, yield, water level, aquifer properties were generated and utilised to depict the prevailing aquifer systems of the basin (**Annexure-1**). Similarly wells drilled by state department, 90 no,s wells drilled upto to the depth of 60 m bgl was used for deciphering the first aquifer. (**Annexure-1**).

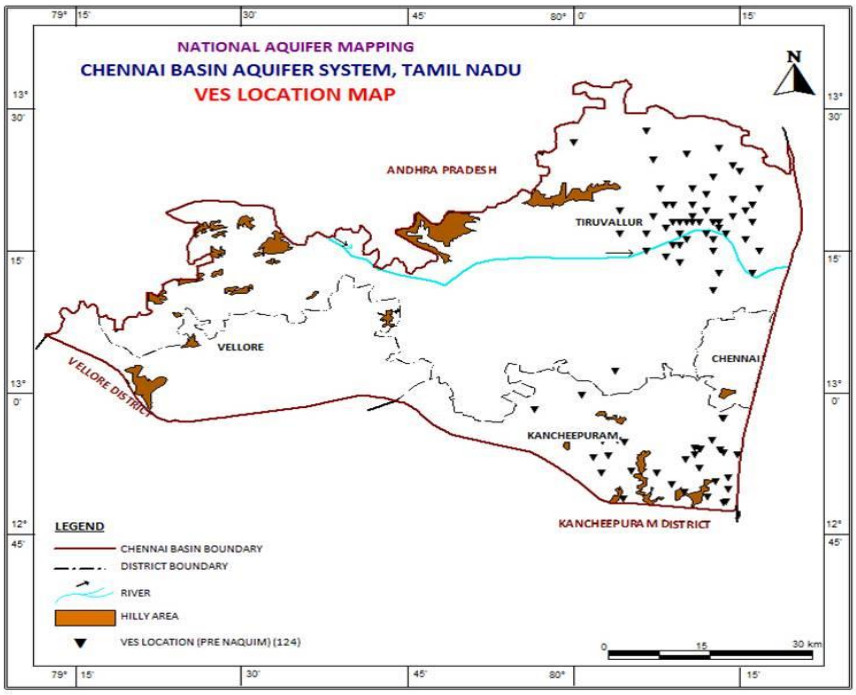


Figure.13 Location of Vertical Electrical Sounding Sites

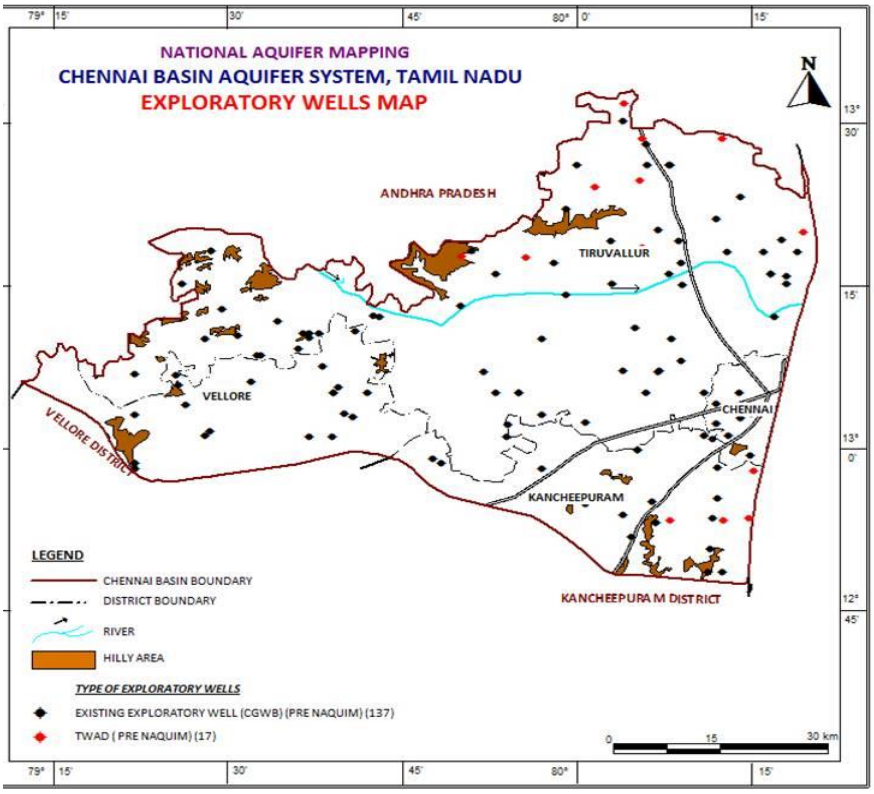


Figure 14 Location of all Exploratory Wells

3. Data Interpretation, Integration and Aquifer Mapping
3.1 Hydrogeological Data Interpretation

Hard rock region :

Hard rock region comprising of gneissic and Charnockites rocks is found in the western and in the south eastern portion of the Chennai aquifer system. Hard rock regions cover an area of 1914.13 sq,km. The Gniessic formation covering an area of 1354.7 sq.km encompasses 18 firkas (figure and Table). The Charnockites formation covers an area of 536.5 sq.km and is found in 17 firkas (Table). The Gniessic formation and Charnockites formation form two aquifer units namely the weathered and fracture/jointed aquifer unit.

Aquifer Unit I – Weathered : The weathered aquifer unit occurs from the groundwater level and has a minimum thickness of 8 m and maximum thickness of 30 m with average thickness of 18 m. 2D disposition along west to south east (figure.) clearly shows the vertical and lateral distribution of the gneissic and charnockitic formation. Yield of this weathered aquifer unit ranges from 0.8 to 16 m^3/hr. During monsoon period the wells tapping this aquifer unit sustains for 2 to 4 hrs/day while during non-monsoon period (April to June) sustains for less than 1 hour/day. Groundwater occurs in unconfined condition.

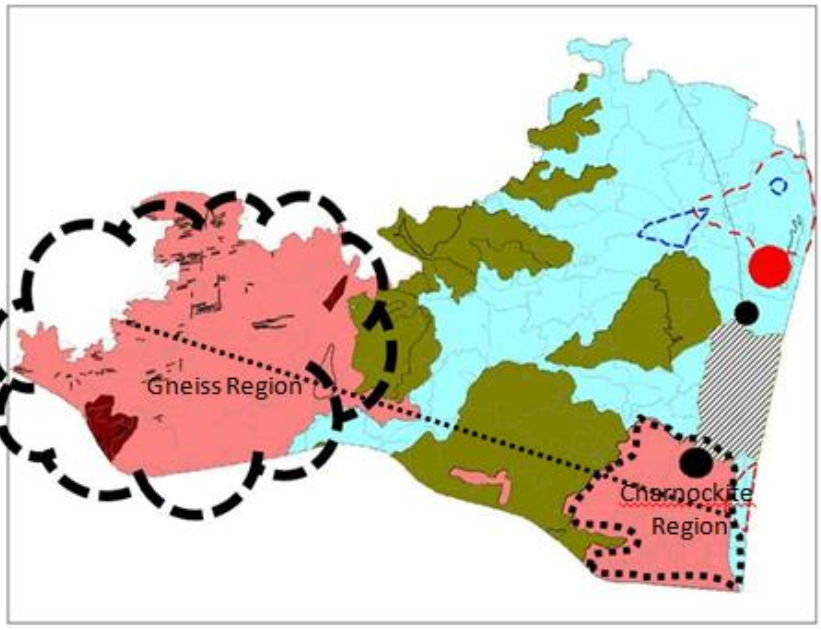


Figure. Spatial distribution of the hard rock region of the Chennai aquifer system.

Table. Name of firkas in hard rock regions

Formation	Name of the firka
Gniess region: (18 firkas)	Melpadi, R.K.Pettai, Cheukkanur, Erumbi, Ranipettai, Velam, Banavaram, Nemilli, Paranji, Arakonam (s) and north Panapakkam, unimangadu, Tiruthani, Ammoor, Pothaturpettai & Kannamachathiram.
Charnockitic region : (17 firkas)	Pallavaram, Chitlapakkam, Tambaram, Padapai, Kunrathur, Guduvancheri, Tiruporur, Pammal, Madambakkam, Medavakkam, Sholinganallur, Kel'bakkam, Pallikaranai, Alanthur & Katt'kalathur.

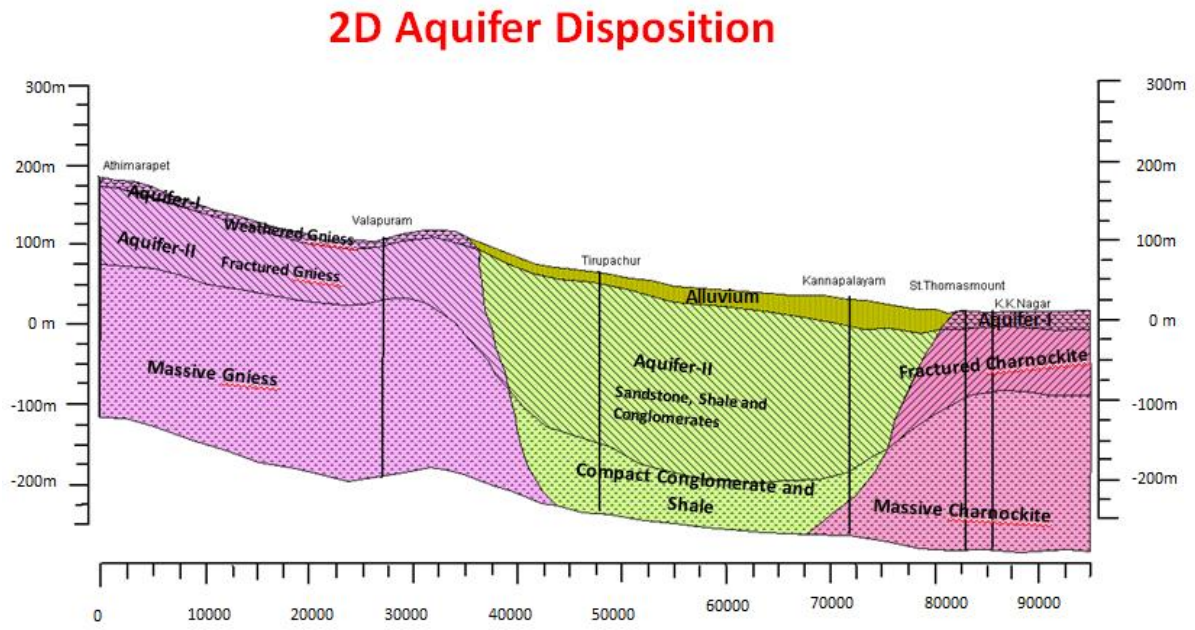


Figure 2D disposition of the Chennai Aquifer system

The aquifer parameter such as transmissivity in this aquifer unit ranges from 4 to 32.3 m^2/day. The Specific yield of this aquifer unit ranges from 1 to 1.5% with highly potable groundwater quality. The general EC of this aquifer unit ranges from 500-600 µS/cm and is suitable for drinking. There are some isolated pockets adjoining the industrial cluster in Chromepet where the groundwater quality is beyond permissible limit for drinking and irrigation purposes. (table).

Aquifer Unit II (Fractured/Jointed) – This aquifer unit comprises of fractured and jointed gneissic and Charnockites formed due to tectonic activity. Top of this aquifer unit occurs from 8 to 30 m bgl. Based on the analysis of the 177 wells it is observed that there is a possibility of occurrence of 3 to 4 Fractures/joints exists upto 190 m bgl in the gneissic region. In Charnockites region 3 to 4 fractures are likely to be encountered and they exit only upto 155 m bgl. The distribution of the fractures with depth is given in table The yield of this aquifer unit II ranges from 0.9 to 12 m^3/hr. During monsoon period the wells tapping this aquifer unit sustains for 4 to 6 hrs /day while during non-monsoon period (April to June) sustains for 1 to 3 hour/day. Transmissivity of this aquifer unit ranges from 3.57 to 45.58 m^2/day (Table.xx). The general EC of this aquifer unit ranges from 320 to 1040 µS/cm and is suitable for drinking.

Table. Salient features of the aquifer units in hardrock region of Chennai Aquifer System

Type of Aquifer	Formation	Top of the aquifers (mbgl)	Thickness/ occurrence of fractures (m)	Range of Yield (m^3/h)	Sustainability (hrs)	Aquifer parameter (Transmissivity) m2/day)	Groundwater quality EC values (µs/cm)	Suitable for Drinking
Aquifer unit - I	Weathered gneiss & Charnockite	GL	8 – 30 (Avg. -18 m)	0.8 -16	Monsoon : 2-4 hrs & non monsoon (May,Jun &July) < 1 to 2 hrs	4 to 32.3	500-600	yes
Aquifer Unit -II	Jointed & Fractured Gneiss/ charnockite	8 to 30	8 -190 (3 to 4 fractures exist)	0.9 -12	4-6 hrs in monsoon & 1-3 hrs in non - monsoon	3.57 -45.58	320-1040	yes

Table . Distribution of fractures in the hard rock formation

Gneissic formation (177 wells)		**Charnockite region (177 wells)**	
Depth (m bgl)	**% of fractures**	**Depth (m bgl)**	**% of fractures**
Upto 50	50	Upto 50	48
50 to 100	36	50 to 100	34
100 to 190	14	100 to 155	18

Gondwana region:

This Gondwana region comprises of highly compacted Conglomerates of upper Cretaceous with type area being the Sathyavedu formation and is located 5 km of the north/central periphery. Gondwana region covers an area of 962.40 sq.km (Figure. Spatial) and encompasses 11 firkas (Table. Firka details). Gondwana region with laterite capping covers an area of 321.73 sq.km encompassing 15 firkas (Table.firka) in the Chennai Aquifer system. The maximum thickness of laterite capping is 8.4 m. Gondwana region forms two aquifer units namely aquifer unit I comprising completely weathered Gondwana and Gondwana with laterite capping and aquifer unit II comprising of fractured Conglomerates. These are generally poor yielding aquifer units.

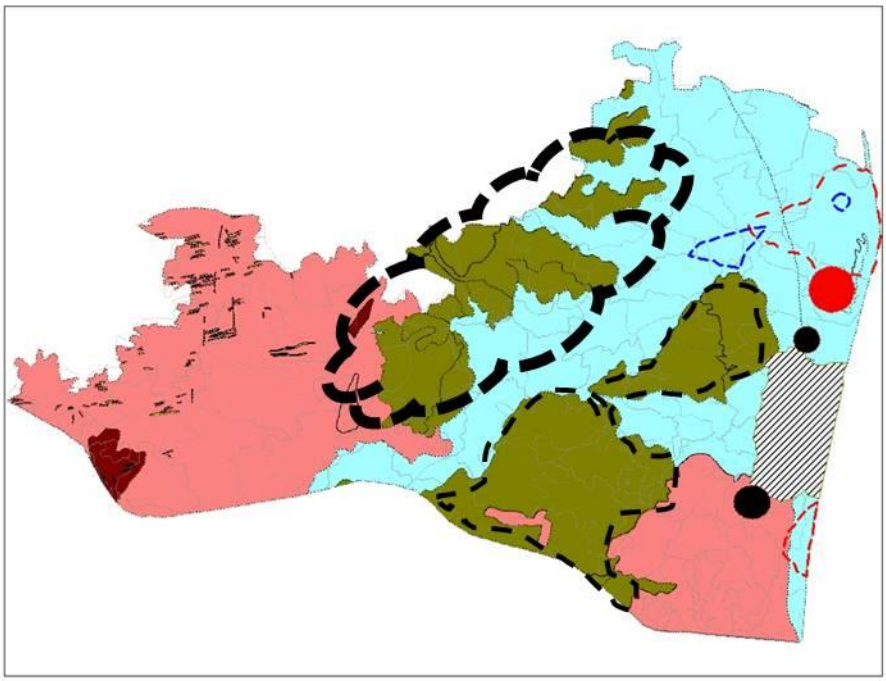


Figure. Spatial distribution of the Gondwana region in the Chennai Aquifer System

Formation and number of firkas	**Name of the firkas**
Top Gondwana (11 firkas)	Poovalambedu, Poondi, Manavur, Pandur (p), Thiruvalangadu, Pennalurpett, Velakapuram & Uttukottai
Laterite capping on Gondwana (15 firkas) Laterite capping on conglomerates (max 8.4 m)	Vengathur, Thandalam, Mappedu, Valam, Parandur, Sunkuvachattram, Tiruninvarur, Avadi, Morai, Cholavaram, Tiruvur, serappanacheri & red hills.

Aquifer Unit I: This aquifer unit comprises of completely weathered conglomerates and conglomerates with laterite cappings. The top of this aquifer unit occurs from ground level to 6.5 m bgl. The thickness of this aquifer unit ranges from 9 to 13.50 m bgl. The maximum thickness of the laterite deposit is 8.4 m and is observed in the southern portion of the Chennai aquifer system. 2D aquifer disposition along northeast-southwest, North-south and north-north east- south-south west is represented in figure …….Yield of this aquifer unit ranges from 2 to 27 m^3/hr. The aquifer unit comprising conglomerate formations yield very low. While conglomerates with lateritic capping have high yield and they range from 4 to 27 m^3/hr. Wells tapping complete conglomerates aquifer unit sustain for 2 to 3 hrs during monsoon and less than hour during non-monsoon period i.e., April to June. Wells tapping the conglomerates with laterite capping sustain for 3 to 5 hrs during monsoon and less than 1 hr/day during non-monsoon (April to June). Transmissivity value ranges from 2.23 to 142.2 m^2/d. Transmissivity are very low in the completely conglomerate region while they have high values in laterite capped regions. Specific yield of this aquifer unit estimated through a long

duration pumping test (7200 min) of the well tapping conglomerate aquifer unit resulted in specific yield value of 1 (CGWB 2014). Groundwater occurs in unconfined condition. EC in this aquifer unit ranges from 150 to 2500 µS/cm.

Aquifer Unit II: This aquifer unit comprises of conglomerates which are cemented by siliceous material and pore spaces and open spaces in the conglomerates stores and yields groundwater. Basically these are good reservoir rocks. This aquifer unit II occurs below the weathered conglomerates and extends upto 764 m (drilled depth in Puduvoyal village). The top of this aquifer unit extends from 9 to 13 m bgl and has thickness ranging from 8.6 m to beyond 300 mbgl. Deepest well drilled in Gondwana is 764 m (CGWB 1981). 2D aquifer disposition along northeast-southwest, North-south and north-north east- south-south west is represented in **figure …….**Yield of this aquifer unit ranges from 2 to 8 m3/hr and can sustain for 1 to 2 hours /day during monsoon and less than 1 hour/day during non-monsoon period (April to June). Salient features of this aquifer unit is presented in **table.(Salient).** EC values in this aquifer unit ranges from 100 to 2125 µS/cm. groundwater is generally potable except for few locations along the eastern part.

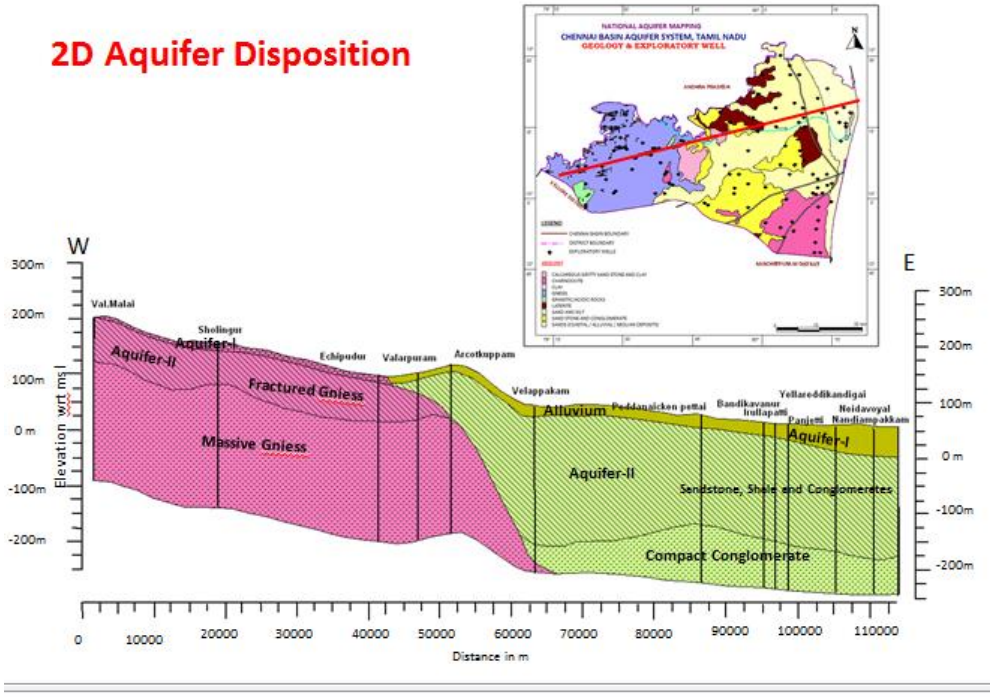


Figure.2D disposition along northeast –West direction.

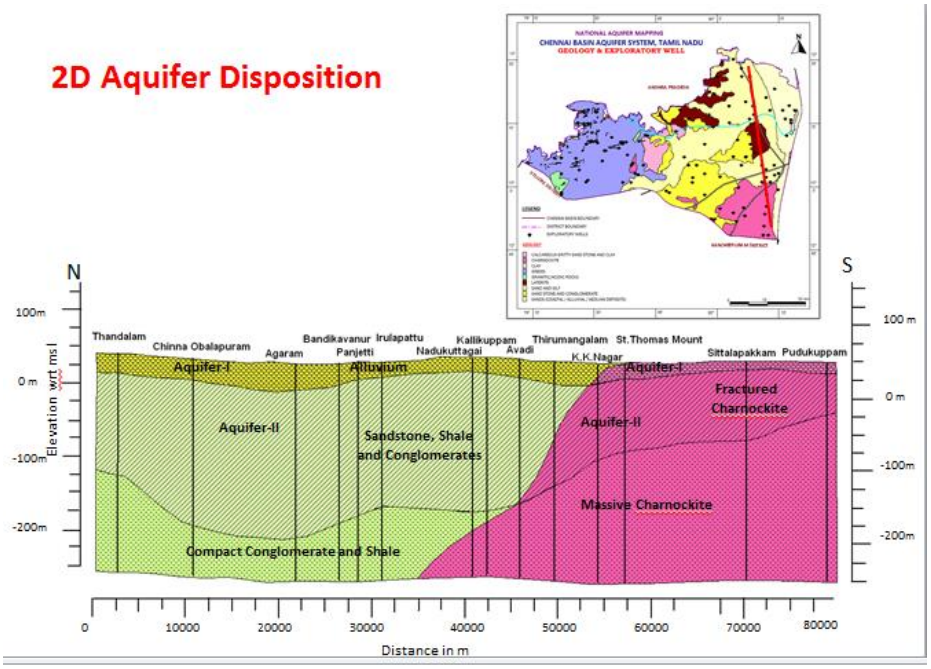


Figure.2D disposition along north –South direction.

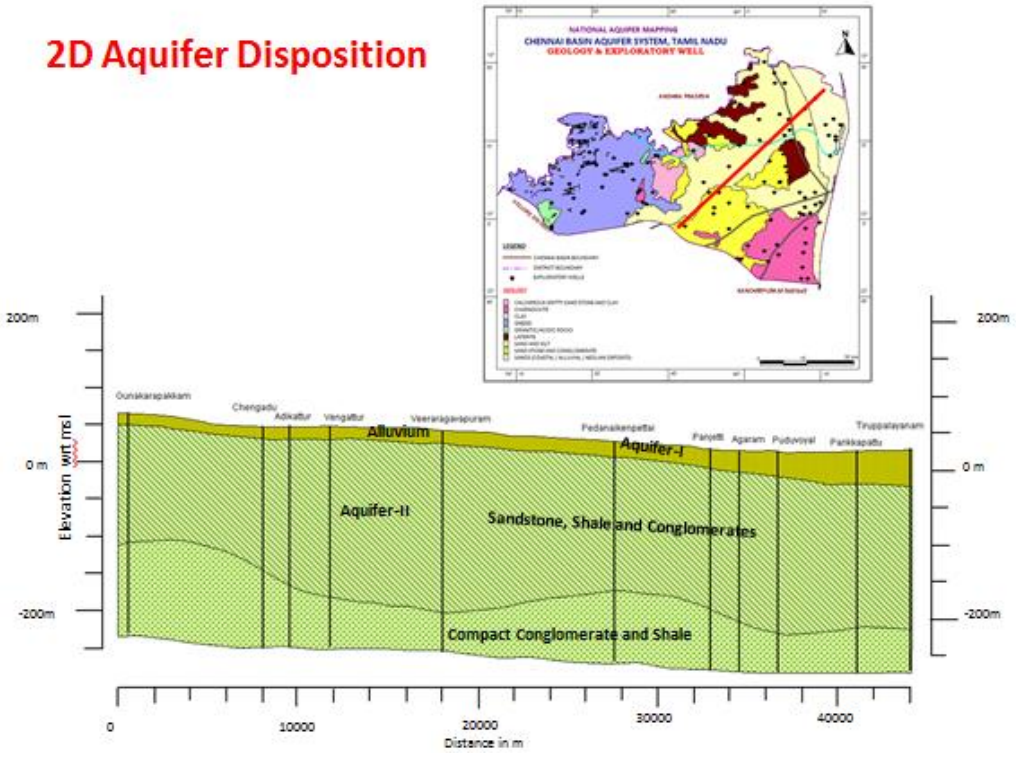
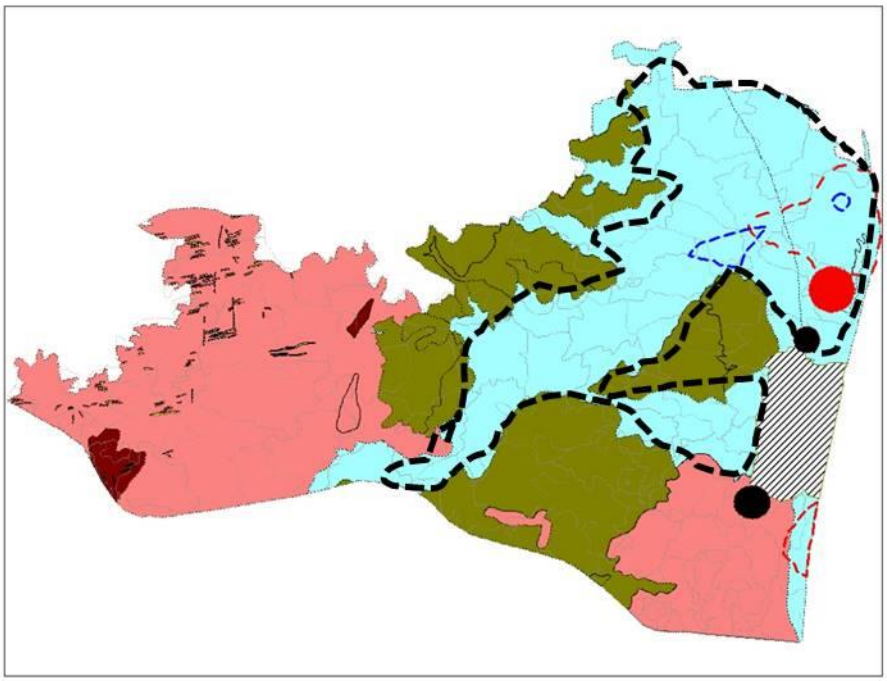


Figure.2D disposition along north-north east –South-South west direction.

Table. Salient features of the aquifer units in hardrock region of Chennai Aquifer System

Type of Aquifer	Formation	Top of the aquifers (mbgl)	Thickness/ occurrence of first fractures (m)	Range of Yield (m^3/h)	Sustainability (hrs)	Aquifer parameter (Transmissivity – m2/day)	Groundwater quality EC values (µs/cm)	Suitable for Drinking
Aquifer unit - I	Laterite capping on Gondwanas (Conglomerates)	GL – 6.5	9 -13.50	2-27	Monsoon : 2-3 hrs & non monsoon (May,Jun &July) < 1 hr/d	2.234 to 142.2	150-2500	yes
Aquifer Unit -II	Tertiary sandstones Gondwanas (Sandstone, Conglomera-tes)	9 – 13.5	8.6-219	2 -8	for 1-2 hours in monsoon and < 1 hours in non - monsoon	1- 10	100-2125	Yes. except sea water intruded area

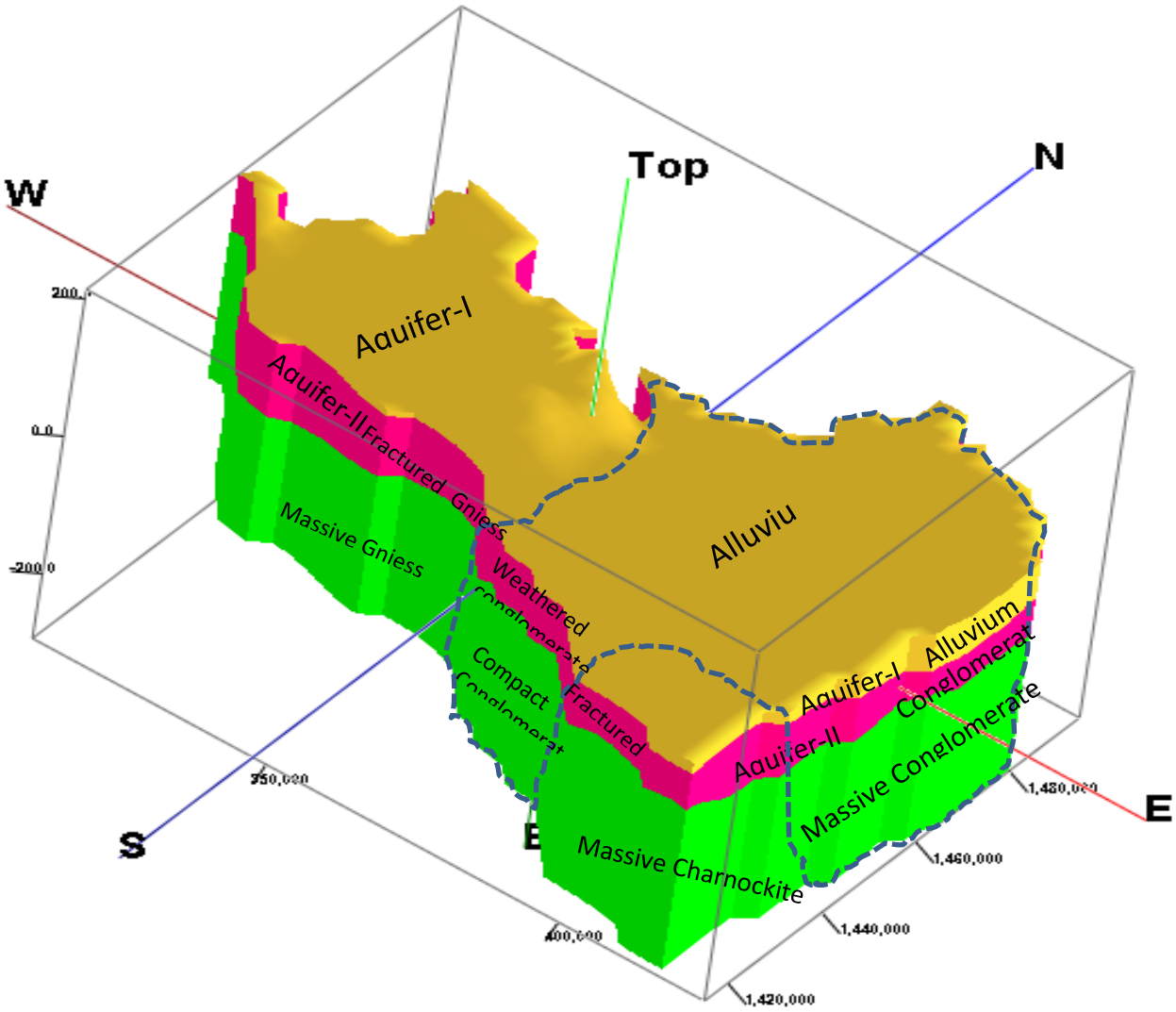
Alluvium Region :

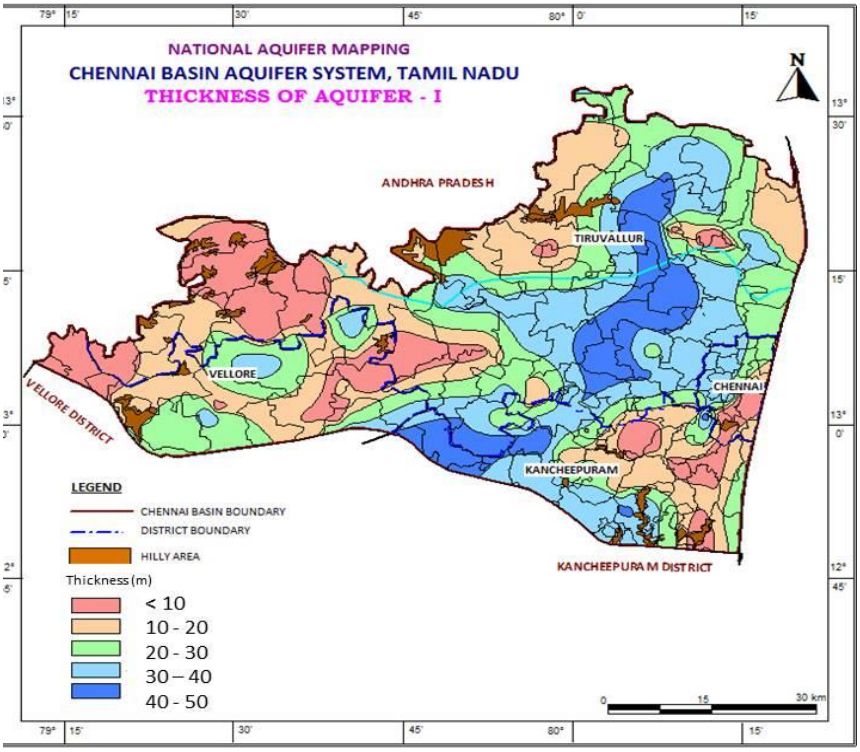


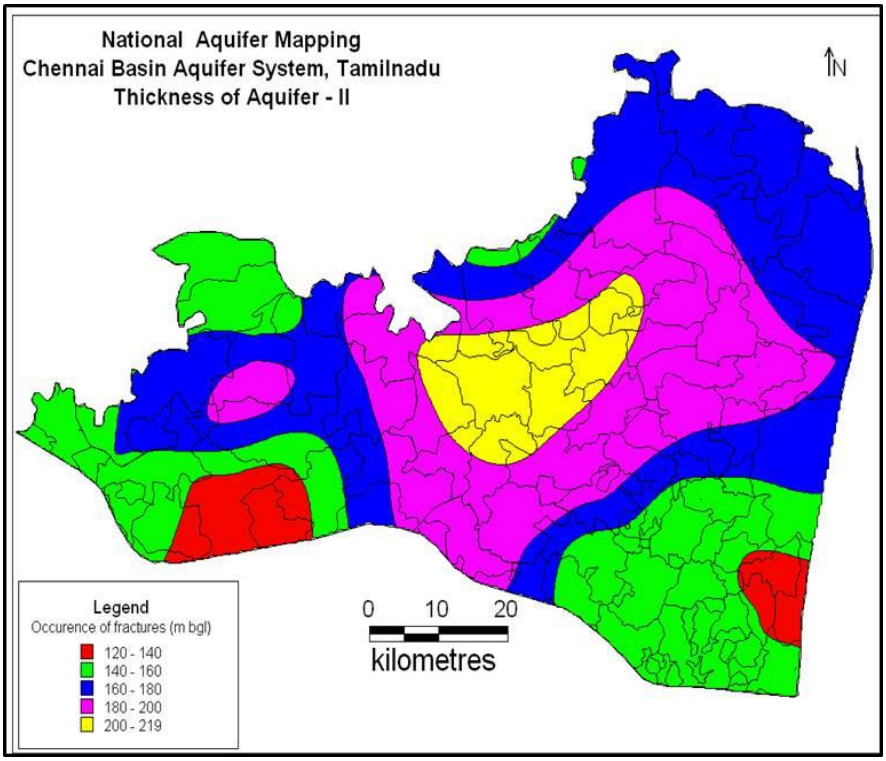
Top Alluvium (47 firkas)

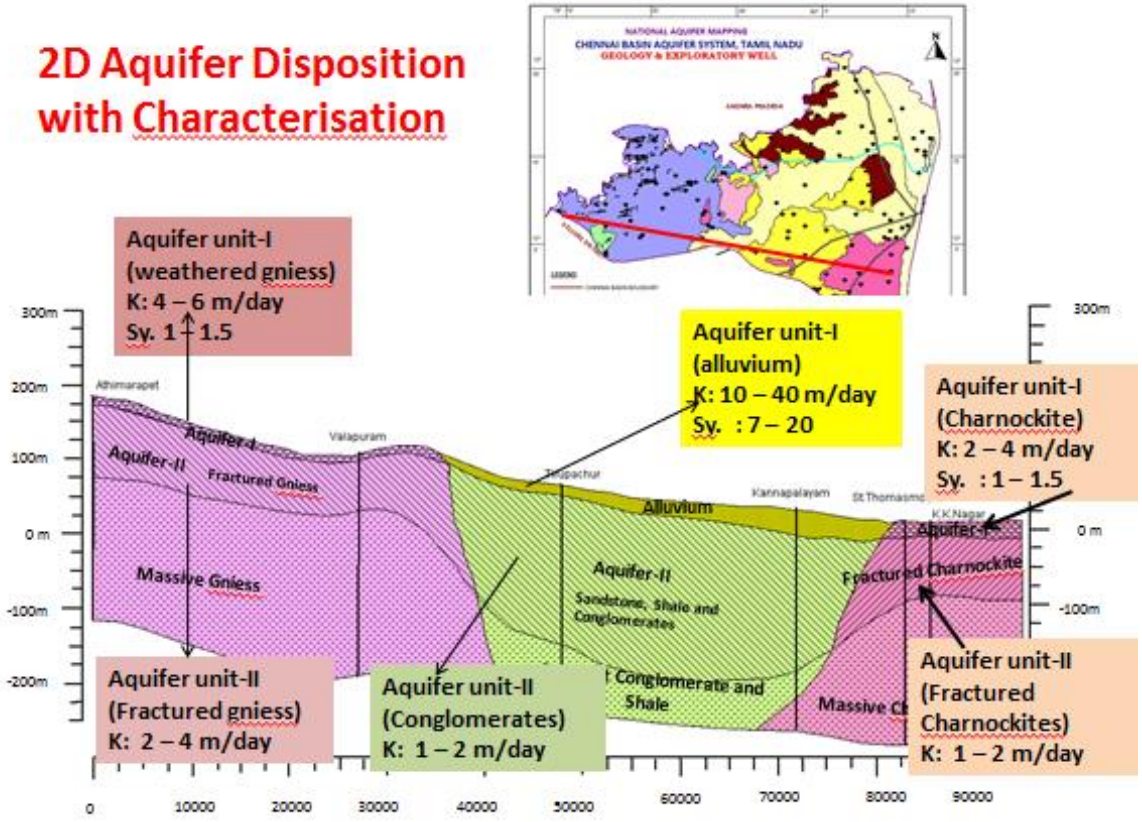
Pallur, Govindhavadi,Kadambattur, Tiruvallur, Pandur, Periyapalayam,Arani, Gummidipondi, Ponneri, Tirumazhisai, Ponnamalle, Maduravoyal, Managadu, Ambattur, Ammanambakkam, Kallur, Elavur, Tirupalaivanam, Gnayar, Minjur, Kattur, Madavaram, All 20 firkas of Chennai

Type of Aquifer	Formation	Top of the aquifers (mbgl)	Thickness/ occurrence of first fractures (m)	Range of Yield (m^3/h)	Sustainability (hrs)	Aquifer parameter – (Transmissivity m2/day)	Groundwater quality EC values (µs/cm)	Suitable for Drinking
Aquifer unit - I	Alluvium Laterites	GL	1-50	68-140	-	1271-4180	422-1103	Yes. except sea water intruded area (EC-6800-13k)
Aquifer Unit -II	Tertiary sandstones Gondwanas (Sandstone, Gravels)	1 to 50	8.6-219	2 -8	for 1-2 hours in monsoon and < 1 hours in non-monsoon	1- 10	100-2125	Yes. except sea water intruded area


W
Top
N
S
E
200.0
0.0
-200.0
350,000
400,000
1,420,000
1,440,000
1,460,000
1,480,000
Aquifer-I
Aquifer-II
Fractured Gniess
Massive Gniess
Weathered
Compact
Fractured
Massive Charnockite
Alluviu
Aquifer-I
Alluvium
Conglomerat
Aquifer-II
Massive Conglomerate


NATIONAL AQUIFER MAPPING
CHENNAI BASIN AQUIFER SYSTEM, TAMIL NADU
THICKNESS OF AQUIFER - I
N
ANDHRA PRADESH
TIRUVALLUR
VELLORE
CHENNAI
VELLORE DISTRICT
KANCHEEPURAM
KANCHEEPURAM DISTRICT
LEGEND
CHENNAI BASIN BOUNDARY
DISTRICT BOUNDARY
HILLY AREA
Thickness (m)
< 10
10 - 20
20 - 30
30 – 40
40 - 50
0 15 30 km


National Aquifer Mapping
Chennai Basin Aquifer System, Tamilnadu
Thickness of Aquifer - II
N
Legend
Occurence of fractures (m bgl)
120 - 140
140 - 160
160 - 180
180 - 200
200 - 219
0 10 20
kilometres



Groundwater Level

During Aquifer Mapping studies in Chennai aquifer system 23 Groundwater monitoring wells which were monitoring regularly were used along with 97 key wells established (**Fig:2.1**) in different formations in order to know the behaviour of the groundwater regime. Out of total 98 wells 46 wells were established in Charnockite, 41 wells were established in Gneiss, 4 wells in Granite, 3 each in Hornblende gneiss and Migmatite formation respectively. The water levels were monitored from May 2014 to Feb 2016 (four times in a year). The depth of key wells ranged from 6.00 to 28.75 mbgl.

3.1.1.1 Depth to Water level for aquifer I (May2014)

Based on the data of key well inventoried and NHS wells, the water level data pertaining to the period of May 2015 (pre monsoon) was used for the preparation of depth to water level map of the basin (**Fig-3.2**). The depth to water level during May 2015 is varied from 1.285 mbgl to 19.83 mbgl. Depth to water level ranging from 0 to 2 mbgl was observed during this period only in 2 wells. Water level ranging from 2 to 5 mbgl is shown in 34 wells (36%), water level

ranging from 5 to 10 mbgl shows in 56 wells (57%). Water level ranging from 10 to 20 mbgl is shown in 02 wells (2 %). Major part of the basin shows water level in the range of 5 to 20mbgl. Patches recorded water level in the range of 2 to 5 mbgl and found in Central and eastern portion of the basin. Water levels ranging 5 to 10mbgl are observed in the whole western part, central part & northern part of the basin. Decadal groundwater average is shown in figure.

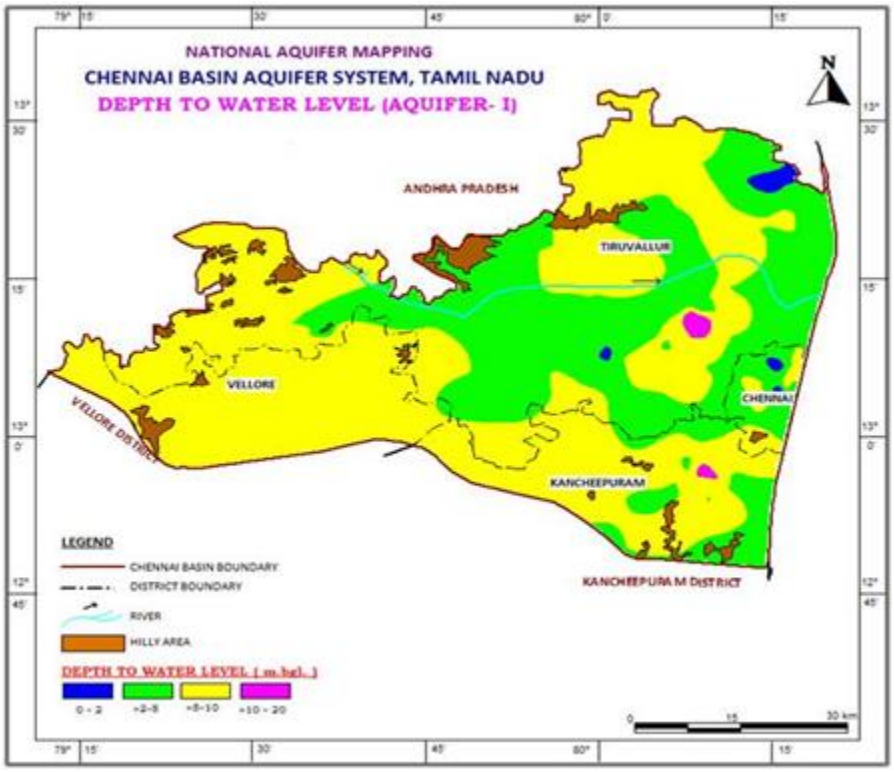


Fig. 3.1 Depth to Water Level – Premonsoon (May 2015)

3.1.1.3. Depth to Water level For aquifer I (Jan-2016)

The depth to water level map for the period of January 2016 based on the key well and NHS data collected from the basin area is presented as **Fig. 3.2**. The depth to water level during Jan 2015 is varied from 0.85 mbgl to 9.7mbgl. Depth to water level ranging from 0 to 2 mbgl was observed in 26 wells (27%). Water level ranging from 2 to 5 mbgl is shown in 59 wells (61%), water level ranging from 5 to 10 mbgl shows in 12 wells (12%). Major part of the basin (61%), shows water level in the range of 2 to 5 mbgl, covering almost entire basin area.

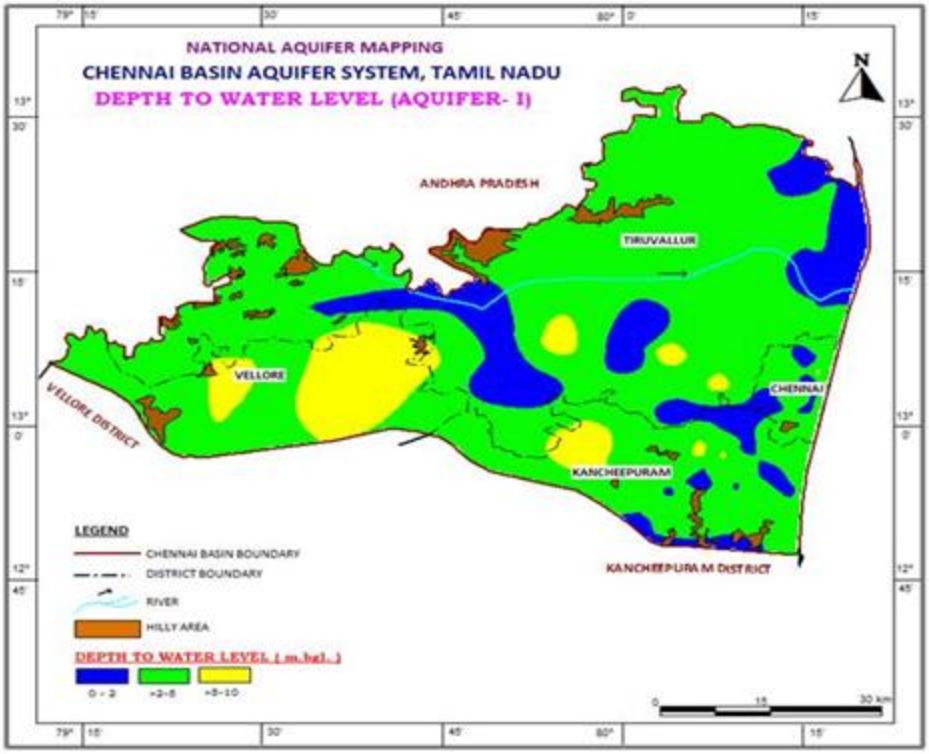


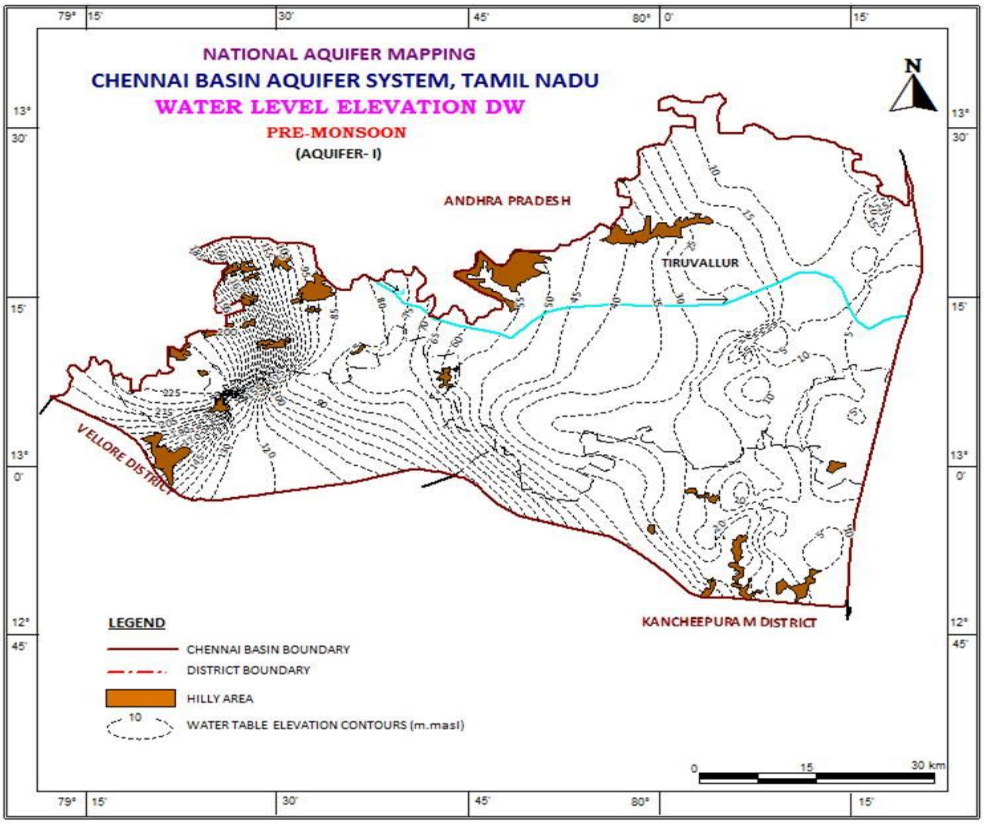
Fig. 3.1 Depth to Water Level – Premonsoon (May 2015)

3.1.1.5 Water Level Fluctuation:

Water level fluctuation in the observation wells in an area between two periods is indicative of the net changes in the ground water storage during the period in response to the recharge and discharge components and is an important parameter for planning for sustainable ground water development. The seasonal water level fluctuation in the area has been analysed using the water level data of May 2015 and January 2016 **(Fig-)**. As both southwest and northeast monsoons are active in the area the fluctuation recorded in ground water levels of January 2016 in comparison to the water levels of May 2015 indicate the extent of replenishment of the shallow aquifer due to the monsoon rainfall.

3.1.1.6. Water Table Elevation :

Water table elevation map of phreatic aquifer of the basin during May 2015, along with flow lines showing the direction of ground water movement is shown in **Fig-3.4.** The water table elevation ranges from 229.3 to 0.22 mamsl in the basin. The groundwater movement is from the west to east part of the basin.



3.1.2. Pumping Tests

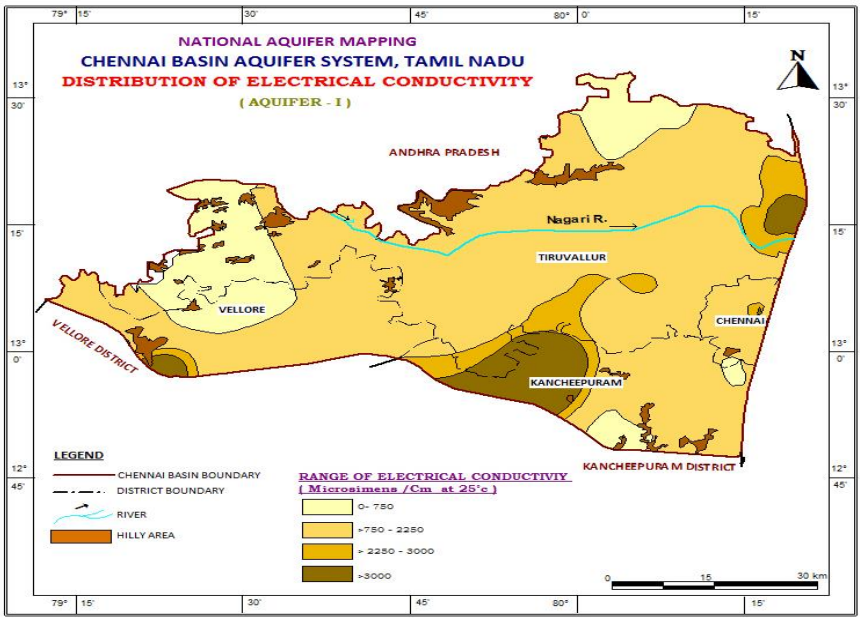
The yields of the wells in the study area are widely varied. Many of Dug wells in the area have less than one meter water Colum during most of the year and about 80 to 95 % of wells get dry during summers. Most of the time dug wells are used as storage tanks to collect water from a number of bore wells and to distribute the collected water for irrigation as the yield of each bore well is much less to support irrigation. The wells located in favourable hydrogeological settings like shear zones, topographic lows, river alluvium etc., are able to sustain at a rate of 100 lpm for 2 to 3 hrs of pumping. The yield of large diameter wells tapping the weathered mantle of crystalline rocks ranges from 20-50 m^3/day for a drawdown of 2-3 m and are able to sustain 1-3 hours of pumping. The specific capacity of the porous weathered formation ranges from 7 to 35 lpm/m/dd. The Transmissivity values of the weathered formation computed from pumping tests ranges from 5 to 20 m^2 /day and storativity ranges from 4.37×10^{-4} to 7.89×10^{-3}. At a very few places the weathered mantle extends down to 19 m bgl.

Groundwater quality

3.2.3. Electrical Conductivity:

Electrical conductivity is the indicator of the total mineral content of water and hence it indicates the total dissolved solids (TDS) present in water. TDS of water determines its usefulness to various purposes. Generally water having TDS <500 mg/L is good for drinking and other domestic uses. However, in the absence of alternative sources TDS up to 2000 mg/L may be used for drinking purposes. The distribution of EC in different aquifers are in Fig. 3.5.

The phreatic aquifer ground water quality is fresh in about 20% , as indicated by the EC value less than 750 µs/cm at 25°C. In about 63% of the Ground Water indicating the moderately fresh showing the EC varies between 751 -2250µs/cm at 25° C, 11% of Ground Water showing EC between 2251-3000 µs/cm at 25° C indicating that the ground water is slightly mineralized and about 6% of groundwater wells the EC is more than 3000 µs/cm at 25°C indicating that the ground water is highly mineralized. The fractured zone ground water quality is fresh in about 18%, as indicated by the EC value less than 750 µs/cm at 25°C. In about 85% of the Ground Water, the EC varies between 751 -2250µs/cm at 25° C indicating that groundwater is moderately fresh and 05% of groundwater are between 2251-3000 µs/cm at 25° C indicating that the ground water is slightly mineralized .There was no Ground Water wells the EC is more than 3000 µs/cm at 25°C during this studies.

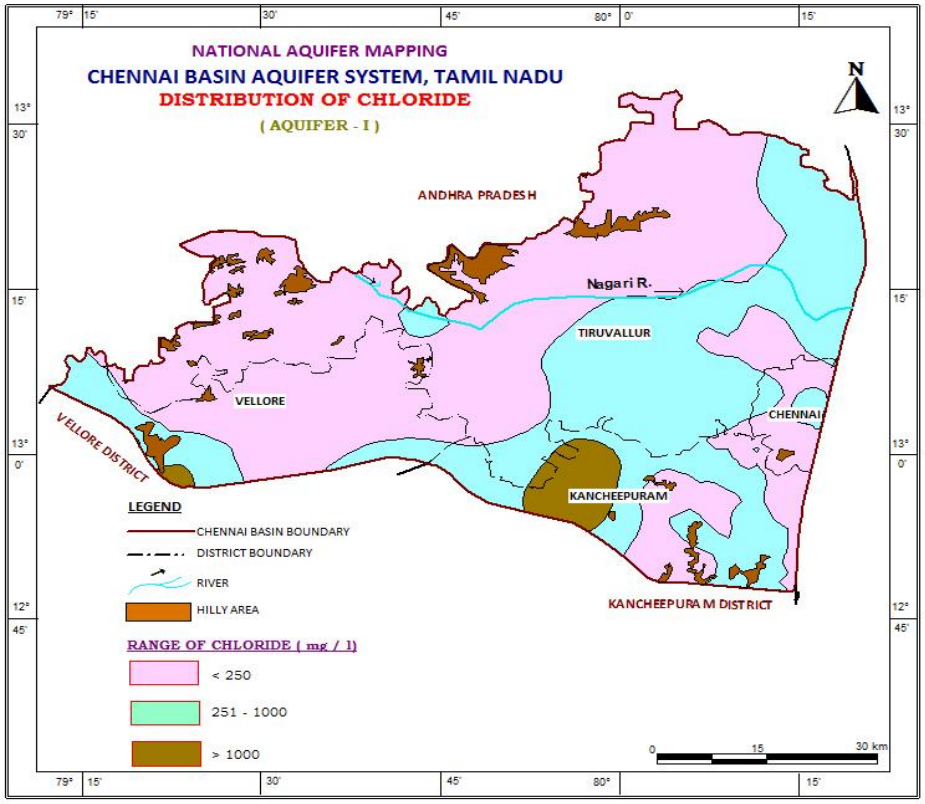


3.2.4. Chloride:

The classification of concentration of chloride in phreatic aquifer groundwater is that about 44% shows with in desirable limit, where as in fractured aquifer 91%shows with in desirable limit., 15% of samples in phreatic aquifer and 9% of samples in fractured aquifer are within permissible limit respectively. There were no water samples shows above permissible limit of Chloride concentration either in phreatic aquifer or in fracture aquifer.

3.2.5 Nitrate:

The concentration of Nitrate in the phreatic groundwater shows that about 45% of the samples nitrate below 45 mg/L, the desirable limit , 55% of the samples showed nitrate between 46-100 mg/L and no samples showed nitrate 100 mg/L, which are above permissible . Nitrate concentration in the fractured aquifer shows that about 49% of the samples nitrate below 45 mg/L, the desirable limit for drinking and 41% of the samples showed nitrate between 46-100 mg/L and about 10% of the samples showed nitrate more than 100 mg/L, which are above permissible limit of Burea of Indian standard (IS 10500:2012).



Ec (us/cm)	Nos.	%	Cl (mg/l)	Nos.	%
0-750	31	25	<250	54	44
750-2250	59	48	250-1000	44	26
2250-3000	19	16	>1000	24	10
>3000	13	10			

3.5. Aquifer Maps

3.5.1. 2D models showing Aquifer Dispossition:

Based on the lithologs of the exploratory wells and the well sections observed during field studies as part of Aquifer Mapping studies, 2D models of the aquifer system of the basin has been deciphered by using ROCKWORKS software. The data input for ROCKWORKS is prepared in following format as shown in **Table-8**, to generate 2D models of the basin along different selected sections.

4.0. Ground Water Resources:

The dynamic ground water resources are estimated as on 2013 based on the methodology suggested by Ground Water Estimation Committee (GEC) 1997.

The ground water recharge is calculated both by ground water fluctuation-specific yield method and by rainfall infiltration method. The annual replenishable ground water recharge is the summation of four components viz.,

i) Monsoon recharge due to rainfall
ii) Monsoon recharge from other sources
iii) Non-monsoon recharge due to rainfall
iv) Non-monsoon recharge due to other sources

Firka-wise dynamic ground water resources have been taken from the approved resources estimation done as on March 2013, jointly by State PWD of Tamil Nadu and CGWB, to arrive at the total resources available in the study basin. Out of the 109 Firkas of the study basin 86 firkas are falling totally in the basin and the rest 23 are falling partly. The resources have been

apportioned to as per the ratio of the firka area within the basin and total firka area for the 23 firkas which are falling partly in the basin.

4.1. Net Ground Water Availability:

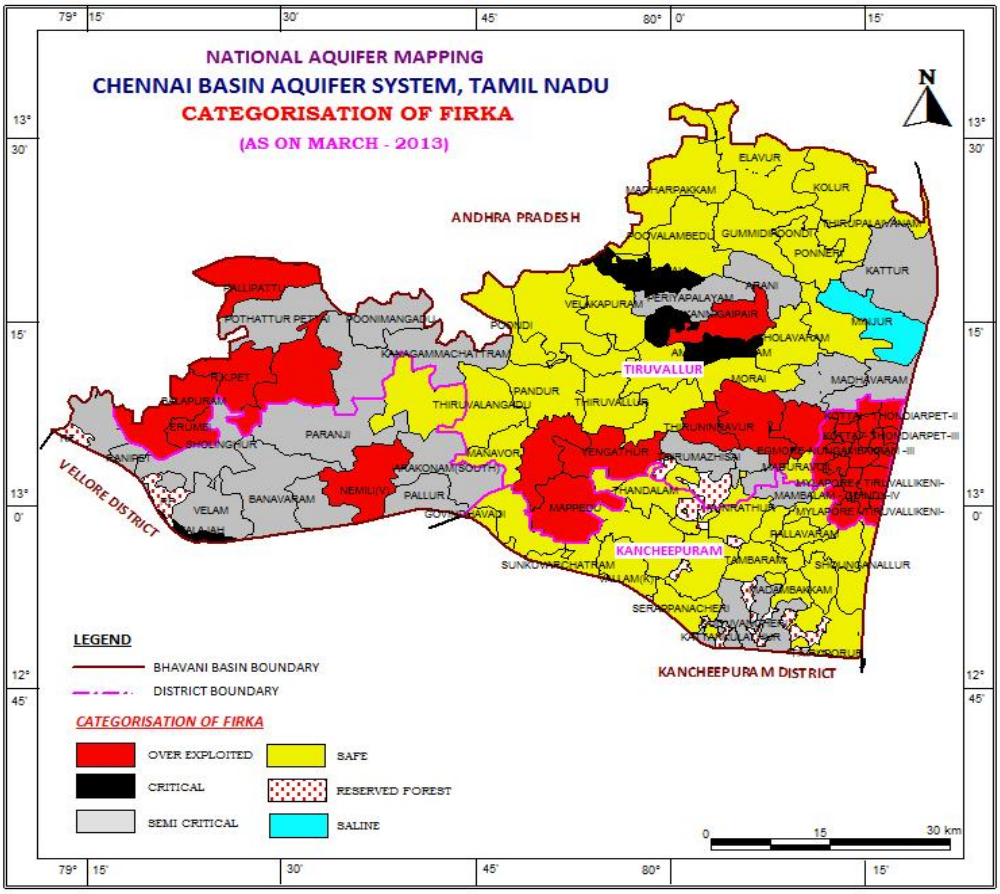
The net ground water availability refers to the available annual recharge after allowing for natural discharge in the monsoon season in terms of base flow and subsurface inflow/outflow. This annual ground water potential includes the existing ground water withdrawal, natural discharge due to base flow and subsurface inflow/ outflow in the monsoon season and availability for future development. As the ground water development progresses the natural discharge gets suitably modified and comes down to negligible quantities due to interception by different ground water structures. Hence, natural discharges in the monsoon season may not be considered and the total annual ground water recharge may be taken as net groundwater availability.

The net ground water availability of the basin for the year 2013 is arrived at 12,4075 Ham, out of which the availability for 20 firkas of Chennai district is 1497 ham, 33 firkas of Kancheepuram 35631 ham, 46 firkas of Tiruvallur 70462 ham and 10 firkas of vellore district-16846 ham **(Table 4.1)**

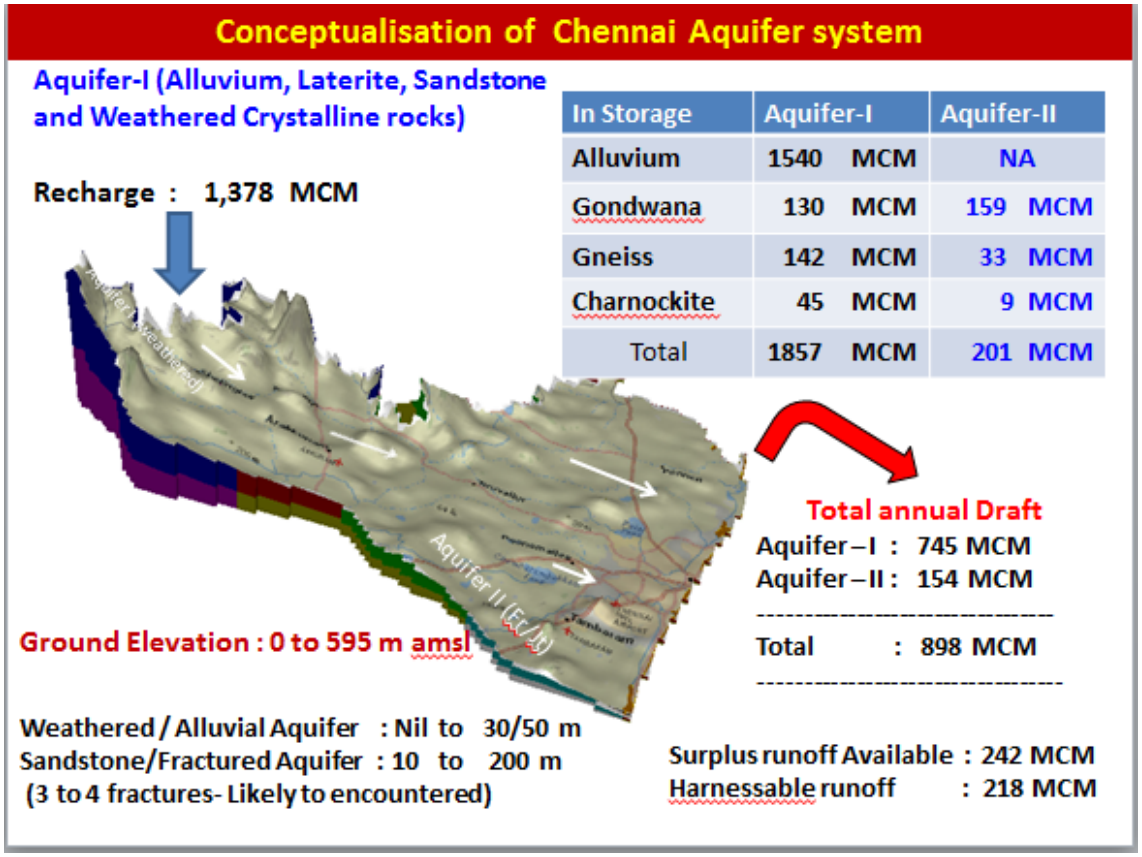
4.2. Ground Water Draft:

The gross ground water draft has been assessed by using Unit draft method for irrigation draft component and by adopting formula suggested by GEC 1997 for domestic and industrial draft components.

The existing ground water draft for irrigation is maximum in Pulikarai Firka (3246 ham) followed by Palakodu (3113 ham), Indur (2411 ham) etc. The gross ground water draft for domestic and industrial uses is maximum at Kadayampatti of Salem district (186 ham) followed by Dharmapuri (113 ham), Mecheri (112 ham). The existing gross ground water draft in Dharmapuri, Krishnagiri and Salem districts is 25,520 ham, 4,615 ham and 3,335 ham respectively. And the total gross ground water draft of the basin is 33,472 ham against the availability of 28,208 ham.



District	Resources (ham)			
	2011		2013	
	NGWA	Draft	NGWA	Draft
Chennai	1707	3780	1497	2768
Kancheepuram	36387	19629	35631	19403
Tiruvallur	72840	49289	70462	48147
Vellore	16724	14393	16486	14156
Total (ham)	**128658**	**89436**	**124075**	**84474**
Total (MCM)	**1286.58**	**894.36**	**1240.75**	**844.74**



4.3. Stage of Development and Categorization:

The stage of development is defined by stage of ground water development (%)

= (Existing ground water draft/ Net Ground water availability) x 100

The stage of ground water development is calculated for all the 109 firkas of the basin The Categorization has been done by considering the two factors as suggested by GEC 97, viz.,

i) Stage of Development

ii) Long term trend of pre and post monsoon water levels.

The following FOUR categories have been suggested by GEC-97 based on the above two factors.

a) Safe b) Semi-critical c) Critical d) Over-exploited

Based on the above categorization 38 out of the 109 firkas of the chennai aquifer system falls under over exploited and critical category. Chennai district all the 20 firkas are over exploited, in Kancheepuram district 4 out of 33 firkas falls under Over-exploited/Critical Category, in Tiruvallur district 12 out 46 firkas and in Vellore district 2 out of 10 firkas fall under over exploited /Critical category. The total state of development of Chennai aquifer system is 68%.

4.4.Static Ground Water Resource:

The ground water available below the zone of water level fluctuation is called Instorage Ground Water Resource. a total quantity of 1857mcm in Aquifer unit I and 21 mcm in aquifer unit-II is available as instorage resource. The instorage in alluvium formation contributes to major portion for the aquifer unit I. table describes the unit wise instorage available in the Chennai aquifer system.

In Storage	Aquifer-I	Aquifer-II
Alluvium	**1540 MCM**	**NA**
Gondwana	**130 MCM**	**159 MCM**
Gneiss	**142 MCM**	**33 MCM**
Charnockite	**45 MCM**	**9 MCM**
Total	**1857 MCM**	**201 MCM**

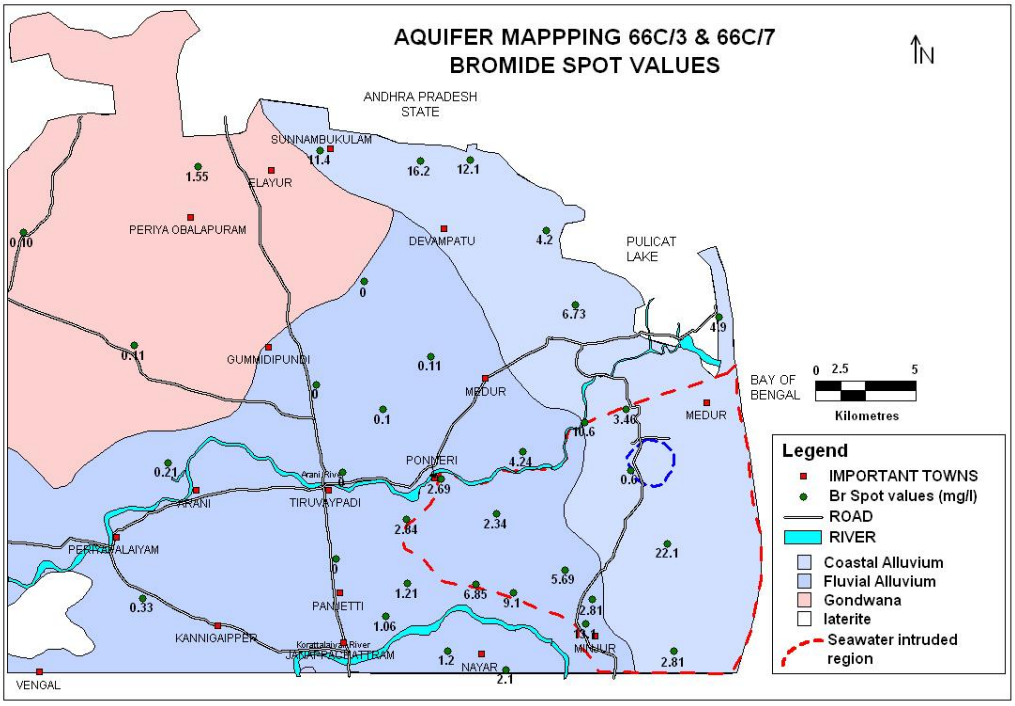
6.0. GROUND WATER RELATED ISSUES:

Ground water is extensively utilized for irrigation in the entire basin area for the past two decades, especially in the 38 over-exploited firkas out of the 109 firkas of the basin. There is no anthropogenic contamination in the basin as there is much urbanization.

6.1.Geographical distribution & Resource availability :

6.2. Ground water quality issues:

Sea water has intruded upto 16 – 16.5 km inland in Minjur - Panjetty area due to the over exploitation of groundwater to meet the Chennai City water supply needs. Figure shows the bromide sampling locations and values clearly demarcating the sweater intruded and non-intruded region.



Following measures can be taken up in the coastal region.

- **Stopping of heavy pumping of GW in the seawater intruded area.**
- **Construction of percolation tanks in the affected area to make fresh water ridge.**
- **Coconut and saline resistance crops are grown in areas having TDS 1500– 2500 mg/l)**
- Mounds on the upstream side of ponds shows groundwater with low EC even in premonsson period there are positive indications of recharge. More ponds can be constructed parallel to the coast and this can create huge mounds of freshwater.
- Artificial recharge structure in the Korattalaiyar river shows improvement in GW Level and GW quality.

6.3. Future Demand Scenario and Stress on Aquifer system:

Future demand projected for domestic utilization will have stress on the aquifer system as the anticipated draft for Chennai city by 2025 would be 1800 MLD which would be 50% increase in comparison to the present gross draft. However, government has implemented desalinization plants to convert saline water to fresh water. Already the dependency on ground water for domestic and drinking needs is increasing and the stage of groundwater development would also increase. The alternative sources from desalinization and augmentation of surface water in flood period are being harnessed.

7.0.Management Strategies

The ground water management strategies are inevitable either when there is much demand to the resource than the available quantity or when the quality of resource deteriorates due to contamination in a given geographical unit. In recent years water resources are used extensively both for irrigation and industrial needs. In addition, to meet the domestic requirements of the fast growing urban agglomerations the administrators are compelled to allocate a considerable quantum of resource which otherwise is being used for irrigation purpose. So, the urbanization has a negative impact on the food production as well as grabbing the employment of the agricultural laborers. Hence, it is the need of the hour to formulate sustainable management of the ground water resource in a more rational and scientific way.

In the present study area of Chennai aquifer system, the sustainable management plan for ground water is being proposed after a thorough understanding of the aquifer disposition down to a depth of 200m bgl. The study area is characterized by weathered and fractured system with very heavy abstraction of ground water for irrigation practices.

7.1. Sustainable Management Plan

The groundwater resource is over-exploited in 38 firkas of the basin comprising an area of 2103 Sq.km. out of the 6288 sq.km area of the basin. Irrigation draft of 844.7 MCM is estimated as per the GEC 2013 against the Net availability of the resource of 1240.75 MCM. A total of 100 MCM in excess was drawn from the ground water system of the 38 OE firkas. Therefore, the usage of groundwater has to be reduced by 40 percent of the existing draft for the sustainability of the resource. Or else the availability has to be augmented through artificial recharge methods to bridge the gap between draft and availability. The draft can be reduced through application of water efficiency methods in irrigation sector and through changing the irrigation practices from wet to dry cash crops.

7.2. Augmentation Plan

Augmentation of groundwater can be achieved through construction of percolation ponds and recharge shafts where the top soil zone is clayey which does not allow infiltration. Normally it

can be achieved through capturing surface runoff. Surface water transfer also can be planned in the absence of surface runoff during droughts. It needs uncommitted runoff from the adjoining localities to transport to the needy areas through diversion channels.

In the study area eastern and southern parts are subjected to Over-exploitation. Normally due to over exploitation of groundwater the water levels are depleting in this zone. The natural rainfall recharge is insufficient to recoup the extracted groundwater. Artificial Recharge and Water Conservation Plans are proposed in the OE & Critical firkas of the basin through utilizing the uncommitted surface runoff of 242 MCM.

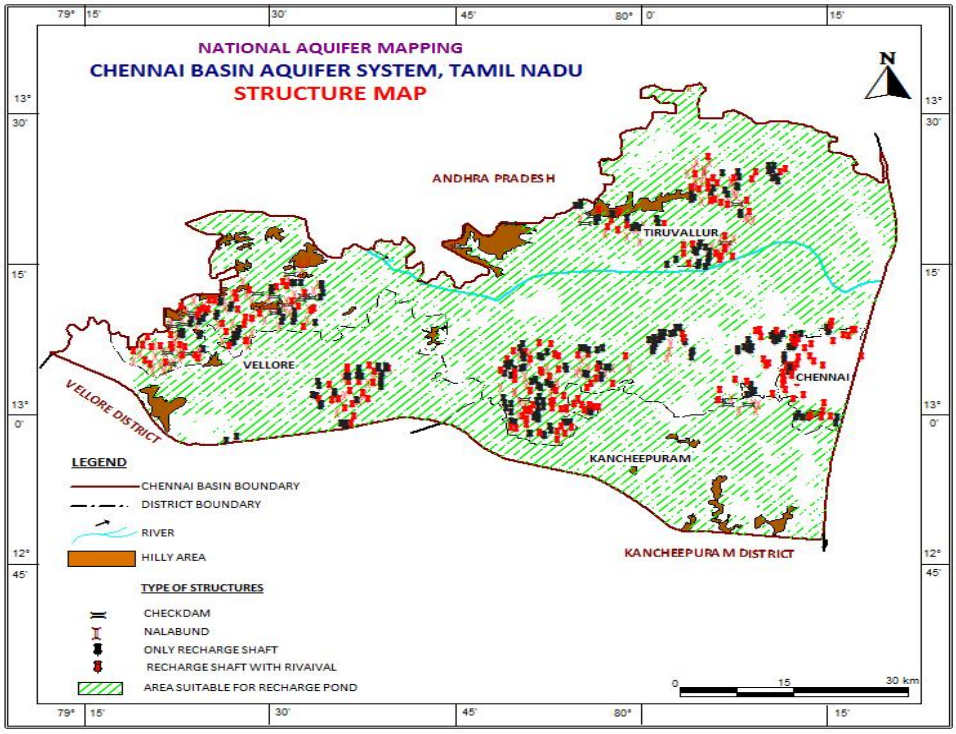
7.2.1. Artificial Recharge Plan

Based on the water level monitoring in different seasons across the basin, as well as after having better understanding of the disposition and extent of the aquifer system through exploratory drilling, pumping tests etc., the potential volume of void space available within the weathered zone of first aquifer of the basin has been estimated as 470 MCM and tabulated in **Annexure - 6**. But the annual uncommitted runoff is only 242 MCM which is less than 50% of required water to fill the available void space of aquifer-I. Artificial recharge and Water conservation plan is prepared for the over exploited firkas of the basin area through harnessing just less than 40% of the annual uncommitted runoff of 54 MCM only with a total out lay of 56 Crore rupees.

The suggested artificial recharge structures are mainly Nala bunds, Check Dams and Recharge Shafts in addition to removal of silt in the surface tanks. Selection of the site locations of these structures are based on the critical analysis of the hydrogeological, geophysical and exploration data of the basin. Particularly geomorphological and drainage aspects are being given more weightage in selection of the Artificial Recharge structures.

A total number of 23 check dams, 166 nala bunds and 372 recharge shafts are proposed in the OE and critical firkas of the basin. A total number of 273 Recharge Rejuvenation ponds are selected for desilting followed by construction of recharge shafts within the tanks. The expected recharge through these artificial recharge structures is in the order of 54 MCM.

The expected benefit by the recharge structures in the 38 OE & critical firka area will be creation of additional crop area of Paddy of 3375 ha or Sugarcane of 2700 ha (or) Banana of 5400 ha (or) Irrigated Dry crops of 10189 ha.

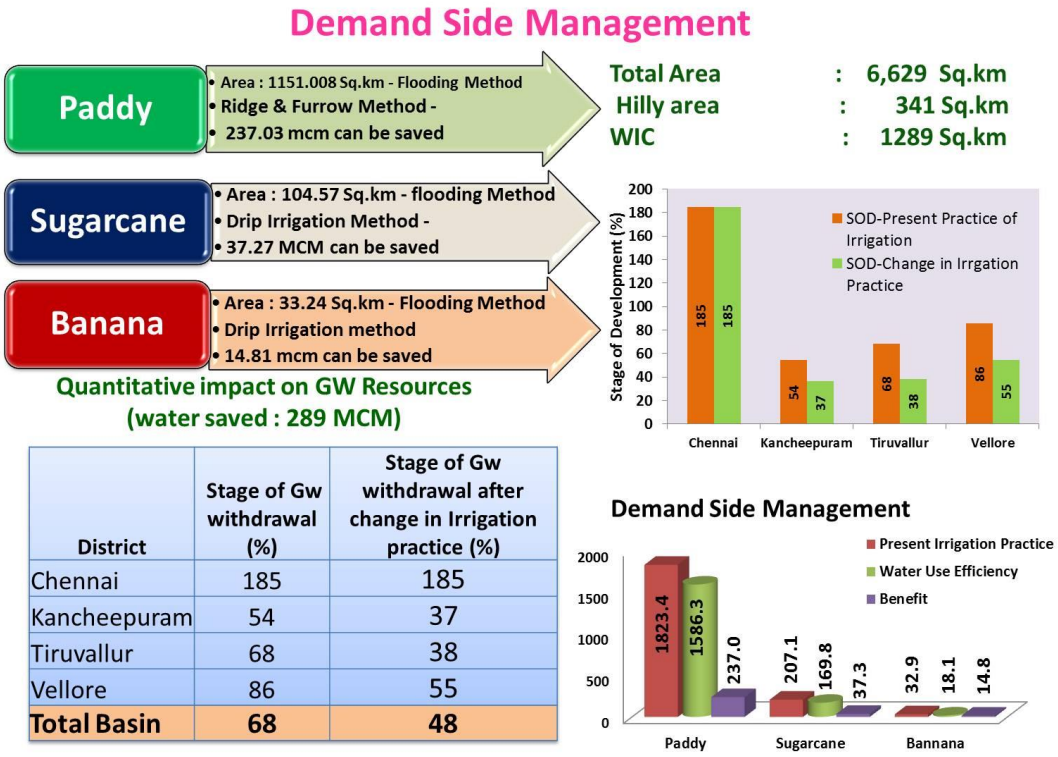


7.2.2. Water Conservation Plan

Low pressure water distribution system is being proposed in 1690 Ha of cropped area which otherwise is under irrigation through earth channels. The expected savings of water through this method is expected to be 3.12 MCM./ yr. A total number of 1690 Farm ponds are proposed which will act as storage tanks in farm as well as augment groundwater recharge and the expected annual groundwater recharge through these ponds is in the order of 7.93 MCM.

7.3.Demand side Management Plan

Demand side management can be accomplished through change in irrigation pattern. It is recommended to change the irrigation pattern for paddy, Sugarcane and Banana crops. The general practice for paddy irrigation is by flooding method. It is recommended for ridge and furrow method instead of flooding method in 1151 sq.km and this would save 237.03 mcm of water annually. Similarly for sugarcane and banana crops shift from flooding to drip irrigation would save 37.37 and 14.81 mcm respectively. The total water saved is 289 mcm.



District	Stage of Gw withdrawal (%)	Stage of Gw withdrawal after change in Irrigation practice (%)
Chennai	185	185
Kancheepuram	54	37
Tiruvallur	68	38
Vellore	86	55
Total Basin	**68**	**48**

The total cost for the change in the irrigation pattern for those water intensive crops would be 455 crores. If Scenario 1 - 30% Area is changed then water saved would be 78.6 MCM. The cost would be 138 crore and the Stage of Development would be lowered from 68 to 62%. In case of Scenario II wherein 50% Area is changed then Water saved would be 131.3 MCM and the Cost would be 233 crore. The stage of Development would be lowered from 68 to 56 %.

Future Demand Stress Aspects

In views of rapid urbanization the domestic water needs are increasing multifold. In this urbanization process the water wastage component is increasing mainly because of leakages through distributor system. Whereas in the agricultural irrigation sector the water demand mainly due to the enthusiasm of the farmers to increase the crop irrigation area.

Hence the policy makers at higher administrative level and rural development authorities at block level should educate the farmers in their jurisdiction in such a way that they should not venture to increase the farm irrigation area. Rather these authorities have to suggest high yielding crop varieties and high-value crops to grow with minimum water requirement with the technical guidance of local agricultural/ agronomic experts.

7.4.Strategies to overcome the future stresses

Future stresses are only hypothetical. If the sustainable management is taken up in a true spirit in consultation with local village level bodies the groundwater depletion will not occur in future. However, it is very difficult to overcome gluttonous user attitude thrives for fullest use of the resource to get maximum output. In this process the vital resource is lost. Therefore a thorough understanding of the consequences of indiscriminate usage of the water should be propagated among users mainly among farmers as they are bulk users of the resource in the study area.

The demand side strategies to overcome future stresses are mainly

- Promoting irrigation pattern change
- Agronomic Water Conservation
- Reducing Water use reduction in Urban areas