POTENTIAL OF SUSTAINABLE WATER RESOURCE MANAGEMENT FOR THE INTERNATIONAL ZONE OF AUROVILLE

A Research Project Conducted by Auroville Water Harvest at the Demand of Auroville International Zone Group and Auroville International Germany

Financed By Auroville International Germany

April 2006

A study conducted by Auroville Water Harvest team, and chiefly

MR.PIERRE JORCIN :	Geographer, GIS expert
MR. SELVAM :	Database developer, GIS expert
MR. K.SIVASUBRAMANIAN:	Hydrogeologist
MR. GILLES BOULICOT:	Director Executive

Report: Gilles Boulicot

SUMMARY

1. INTRODUCTION

Ground water is one of the prime sources of consumable water. It is a major resource for agriculture, industries and human consumption. The advent of modern technologies and the man's increasing quest for optimum use of the available natural resources had its impact on the ground water, which is being excessively extracted without any regulations. In India, Ground water accounts for more than 50% of total irrigated area, 80% of drinking water and other domestic requirements and a sizable portion for industrial requirements. Thus the magnitude of extraction of ground water requires no mentioning, causing adverse effects on the hydrologic balance and quality of water.

The groundwater studies carried out by Harvest (the Implementing Agency) in some of the villages and in Auroville covered by the Kaluvelli watershed showed excessive extraction of ground water in the region and seawater intrusion in some of the coastal villages. The intrusion is also seen in some of the interior villages of the watershed. The possibilities of seawater intrusion in other regions of the watershed were also very likely and if left unattended would jeopardize the entire Vanur region. The consequences of such intrusion would be disastrous, as it will affect the irrigation, which is largely dependent on ground water. The researches carried out by Harvest were displayed in many of the seminars, conferences and meetings with the Governmental and non-governmental organization and were recognized by these agencies.

The International Zone Group of Auroville together with Auroville International Germany has requested **Auroville Water Service - Harvest** to develop a concept of water resource management for the zone. The result of our investigations was delivered in April 2004 as a document called "*A Model of Water Resource Management for the International Zone of Auroville".* The general conclusions brought the attention on three major points:

The extraction capacity (wells) is actually enough to cover the need of the area for the coming years.

Kottakarai village is the main problematic area because of the poor existing sanitation and the close connection with surface water bodies and groundwater.

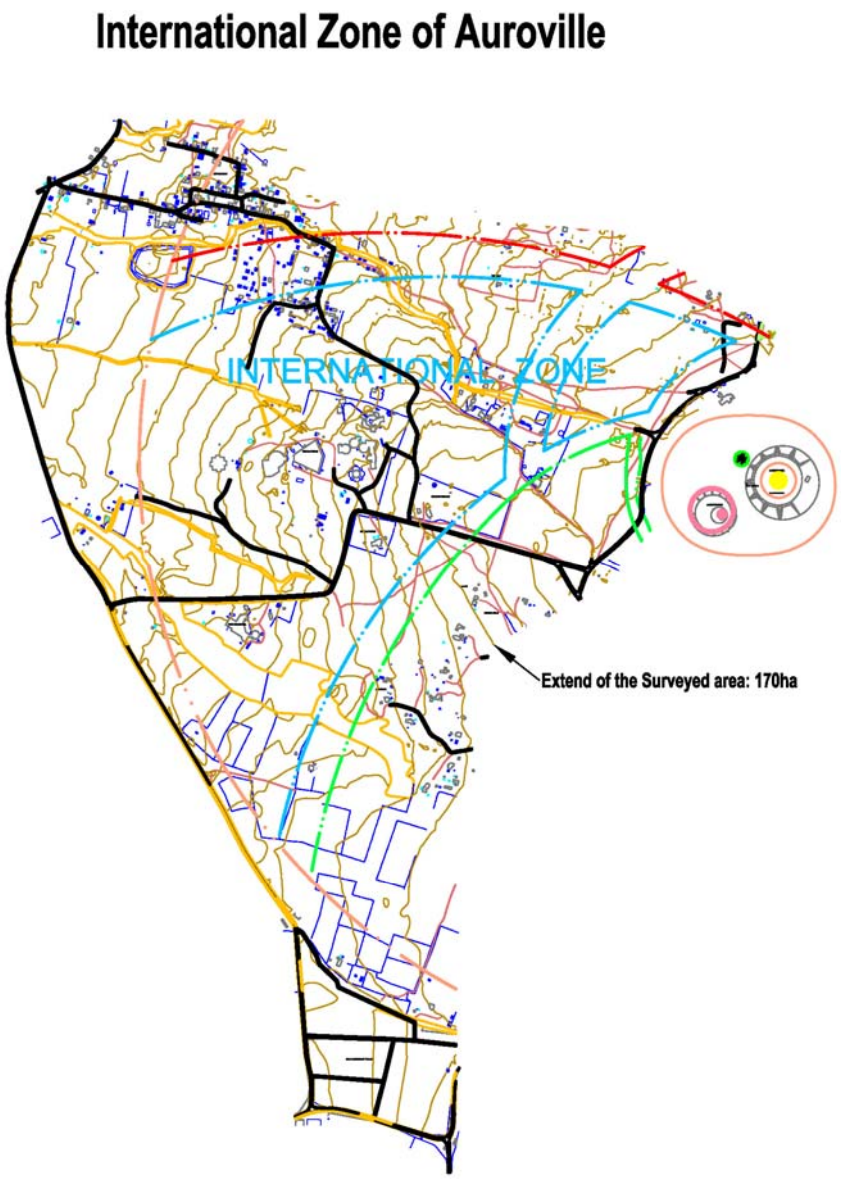
The available data indicate a good potential for sub-surface flow harvesting, which then advocate for a full scale storm water management and integrated landscaping, thus allowing for a reduced stress on the deeper aquifers, already over exploited.

Further investigations are anyhow needed to consolidate the model. Accordingly, Harvest started to work on specific project proposal to target these most urgent questions. A project proposal concerning further investigations is the concern of the present document.

2. LOCATION AND EXTENT

The Auroville Township is located about 8 km North-West of Pondicherry and has presently an aerial extent of 800 ha spread over an area of 42 sq km and lies close to the seacoast. In the north, the area is bounded by the Kaluvelli Tank, and in the south by the Union Tertiary of Pondicherry. In the west, it is bounded by the topo low stretching in the NNE-SSW direction and in the east by the Bay of Bengal. Auroville center is the Matrimandir.

Auroville international zone area is having an extent of about 70 hectares. Anyhow, a correct assessment on groundwater must include the surrounding to have any relevance: the parks, the full village area, the canyons up to their starting area and the land on both side of the tar road. This defines an area of 170 hectares to survey.



3. OBJECTIVES

- To determine the groundwater level fluctuation in the upper part of the aquifer system
- To determine the groundwater flow
- To determine groundwater availability
- To determine the aquifer system's reactivity to rainfall
- To determine the interconnectivity of the aquifers if any
- To determine the most sensitive area of the International Zone and the surrounding as far as environmental impact is concerned
- To determine water logged area extend and its fluctuation in time and space

4. METHODOLOGY

- Weather data collection
- Groundwater level monitoring of 16 wells (January, march and august 2005 are missing) by aquifer systems: Manaveli and Kadaperikuppam
- Geophysical survey to determine ground water occurrence and geological structure particulars
- Infiltration tests all over the area, with more emphasis on drainage structures.
- Data processing and analyses
- Graph generation for piezometric level variation versus rainfall and electro conductivity
- GIS integration
- Contour map generation with reference to topographic contour, salient features existing on the ground (canyons & drains, water bodies, roads, buildings, outcropping geological setup), planned main features (delineation of zones) and rainfall pattern
- NOTE: considering the strong consistency between the Manaveli and Kadaperikuppam water level, both set of data are processed together.

5. PHYSIOGRAPHY

The center of the Auroville Township is located on a high ground at an altitude of 52m above mean sea level (msl) recording steep and gently slopes in the west and east, gradients being 0.6 to 1.1 % respectively. The high ground runs in the NNE-SSW direction being parallel feature to the topo low in the western part.

There is no perennial river system in the area. The shallow Kaluvelli swamp, located to the north of Auroville, is a natural wetland with an aerial extent of 72 sq km and forms the main outlet for the drainage of the northern and

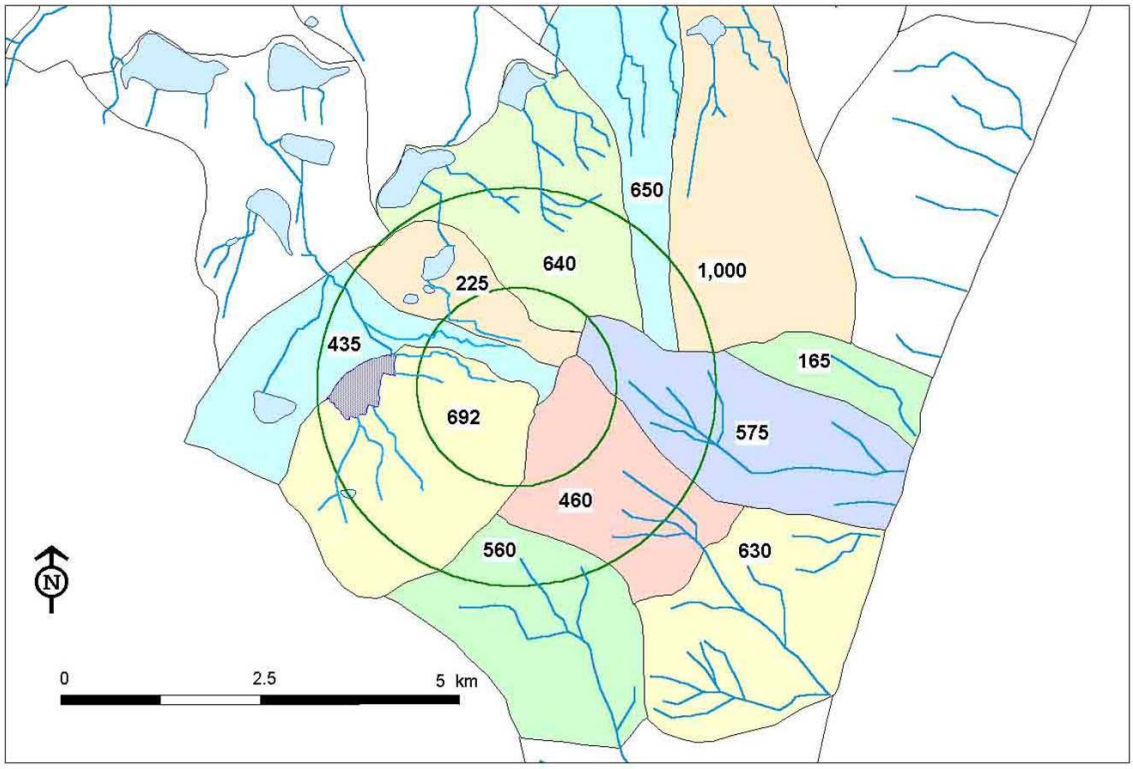
western parts of the Auroville area. Man made irrigation tanks (Erys) and interconnecting channels are present all over this area.

Along the high ground, short flow courses of well-formed gullies drain towards west (topo low) are observed. Similarly, a few canyons occur in the eastern slope of Auroville that drain towards the sea.

Accordingly, the International Zone of Auroville is on the head of a sub watershed covering about 135 sq km and ending in Kaluvelly wetland.

Most of the International Zone is on the drainage area of the Irumbai irrigation tank, but a small part starting at Matrimandir is drained through a channel going through the sub watershed and connected further to other tanks.

DRAINAGE AND MICRO-WATERSHEDS LIMITS AND AREA (IN Hectare) IN AUROVILLE AREA



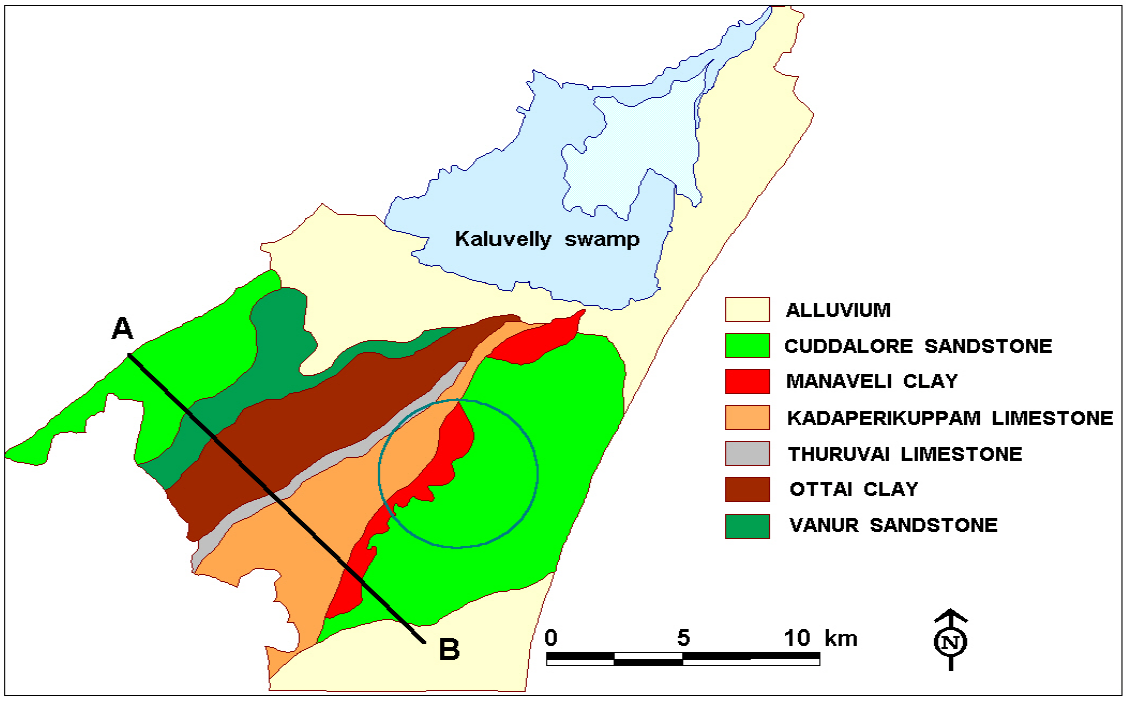
6. GEOLOGY

6.1. General situation

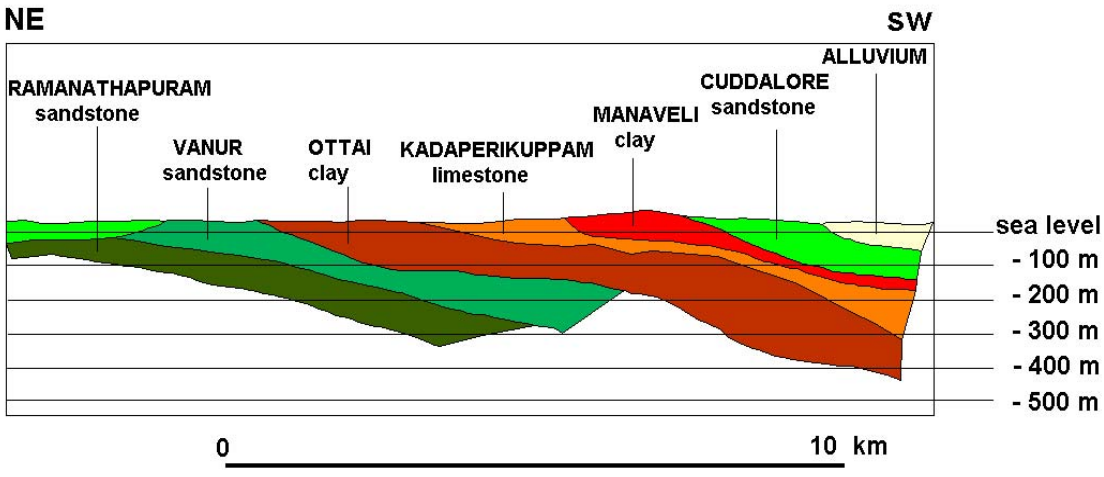
The Kaluvelly watershed, 760 sq. km area, is build of Archean bedrock (Geological map of India, 1/1000 000,Geological survey of India, 1958), which outcrops on the western part (¾ of the total area), overlaid by Mesozoic and Cenozoic sedimentary beds. The bedrock is made of charnokites (rock intermediate between a plutonic and a metamorphic one, with granite composition: K feldspar, Quarts, plagioclase, hypersthene's and some biotite).

They are considered to be highly fractured in the first 100-m and compact in depth. Sedimentary beds lay on the down streamside of the watershed. They are made of sandstone; limestone and clays refer the geological map. Pleistocene alluvium overlaps the NE part on which lay the Kaluvelly swamps. The sedimentary part is very flat (between 0 to 54 m high) sedimentary beds are characterized by a thickens of the layers from NW to SE, reaching 550m depth on seaside. The layers have a smooth regional dip towards the Bay of Bengal of 2 degree and could be affected by NE – SW and EW faults. A literatim blanket (maximum observed + - 7.5 m) lays on the SW part of the sedimentary basin. On the border of the bedrock, the area is spindled with small charnokite peaks (up to 100m high) the following table shows the stratigraphy sequence.

GEOLOGICAL MAP AND CROSS SECTION LOCATION



GEOLOGICAL SECTION ALONG AB



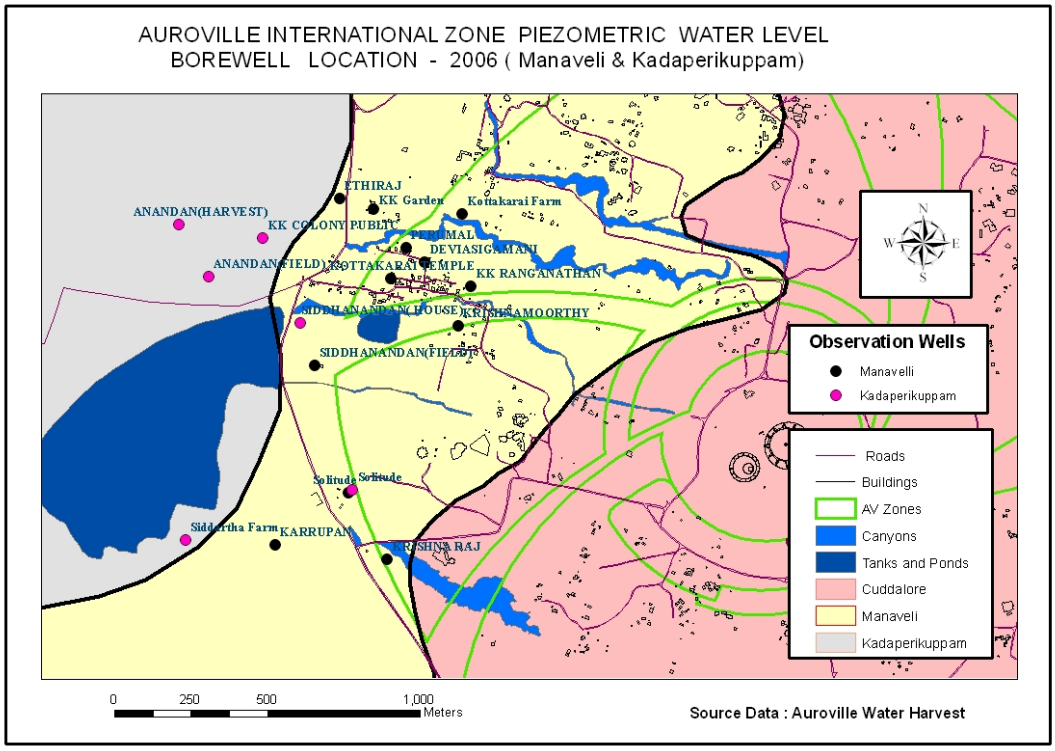
6.2. Stratigraphy successions

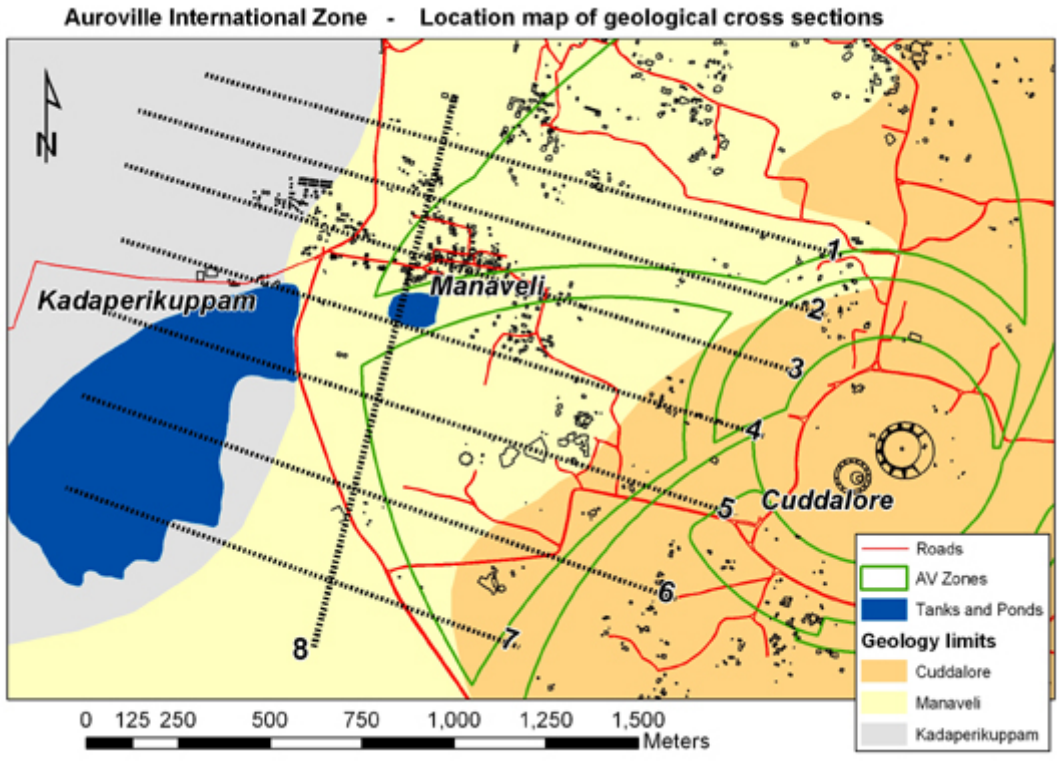
Era	Period	Formation	Lithology
Quart nary	Recent	Alluvium	Sands, Clays, silts, kankar and gravels
Tertiary ----------	Mio-Pliocene ----------	Cuddalore formation UNCONFORMITY	Sandstone, Pebbly and gravelly and coarse grained with minor clay and siltstones and thin seams of lignite. ----------
Tertiary	Pliocene	Manaveli	Yellow and Yellowish, Brown, Grey calcareous siltstone and Claystone and shale with thin bands of limestone.
Tertiary ----------	Pliocene ----------	Kadaperikuppam UNCONFORMITY	Yellowish white to dirty white, sandy, hard fossiliferous limestone, calcareous sandstone and clay. ----------
Mesozoic	Upper Cretaceous	Thuruvai limestone	Highly fossiliferous limestone, conglomeratic at places, calcareous sandstone and clays.
Mesozoic	Upper Cretaceous	Ottai formation	Grayish to Grayish green Claystones with thin bands of sandy limestone and fine grained calcareous sandstone
Mesozoic	Upper Cretaceous	Vanur formation	Quartz sandstone, hard, coarse grained, occasionally felspathic, or calcareous with minor clay.
Mesozoic ----------	Lower Cretaceous ----------	Ramanathapuram Formation UNCONFORMITY-	Black carbonaceous, silt clays and fine to medium grained sands with bands of lignite and sandstone, medium to coarse grained ----------
Achaeans		Easternghat complex	Charnokite and biotite Hornblende gneisses.

6.3. *International Zone Setup*

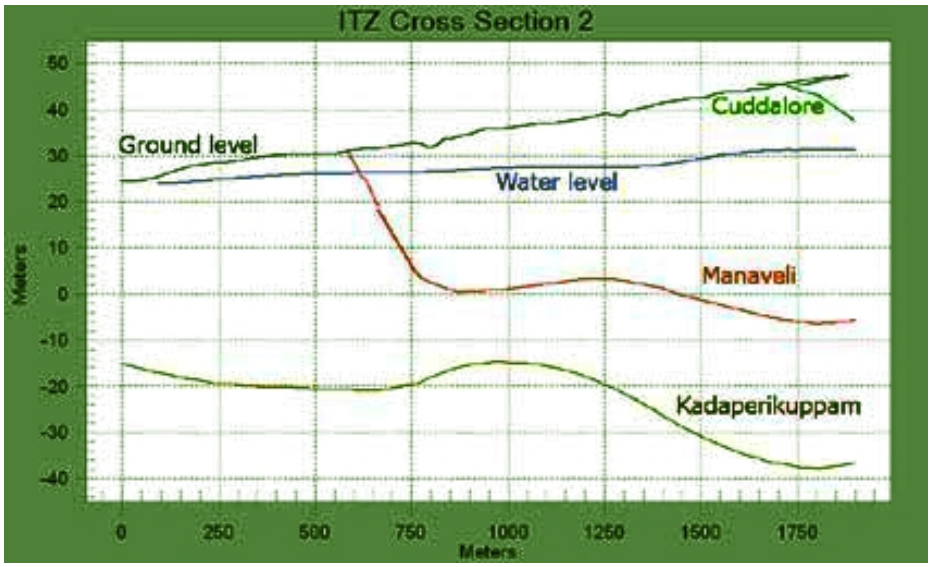
The International Zone is seated on the outcropping part of Cuddalore, Manaveli and Kadaperikuppam formation successively from East to West.

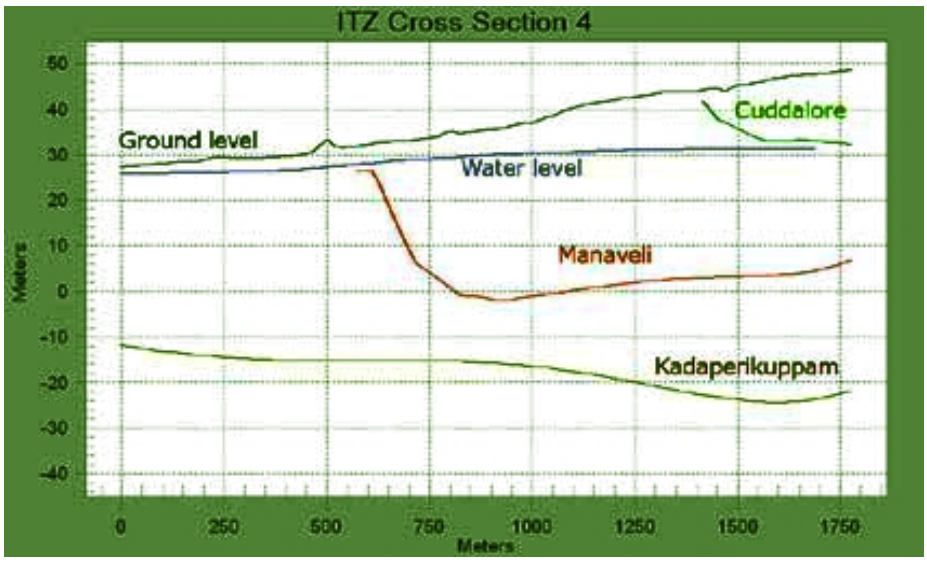
Considering the site condition the other aquifers are not investigated in this study.

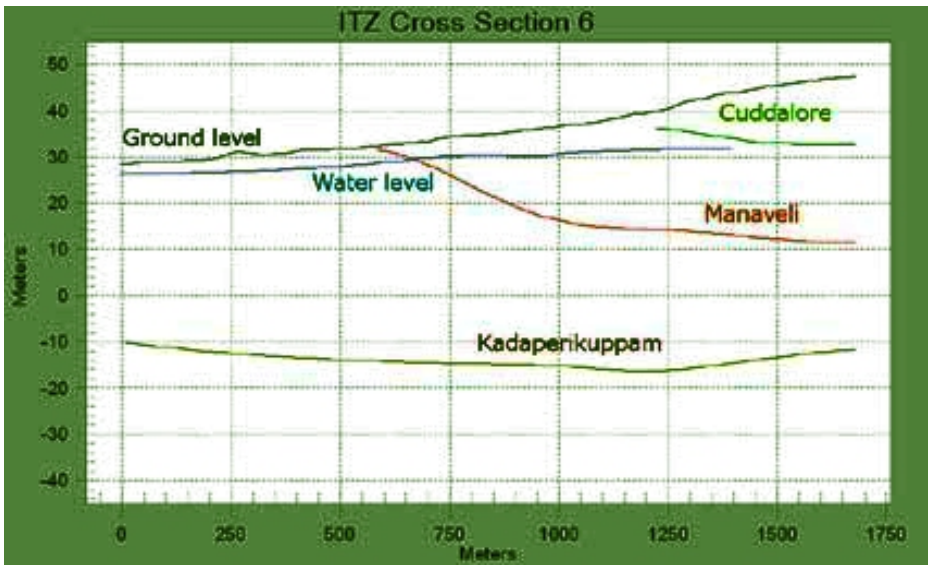


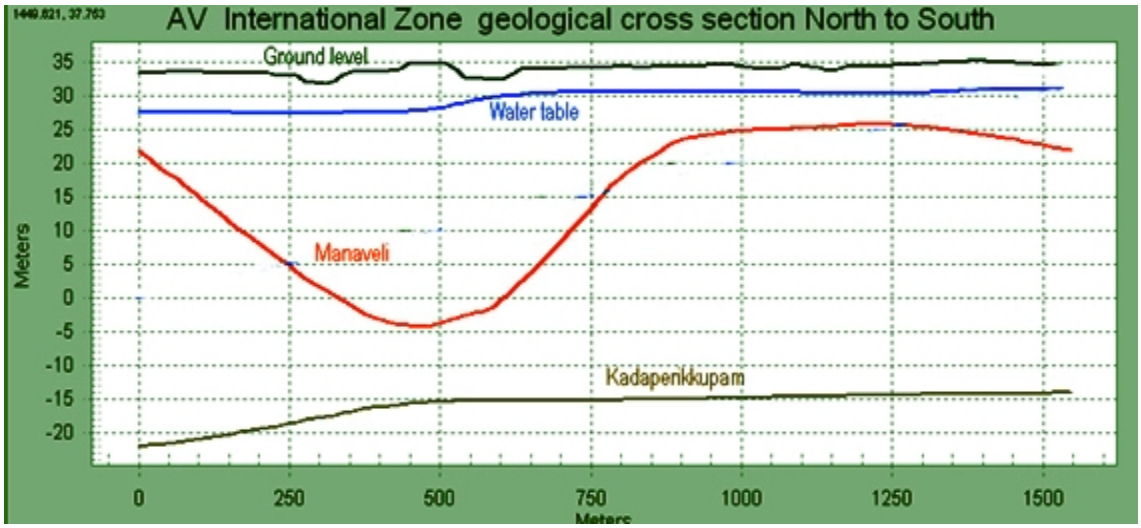


The following sections are based on the limited set of data available from observation wells existing in this area.









7. GROUND WATER MOVEMENT AND AQUIFER PARAMETERS

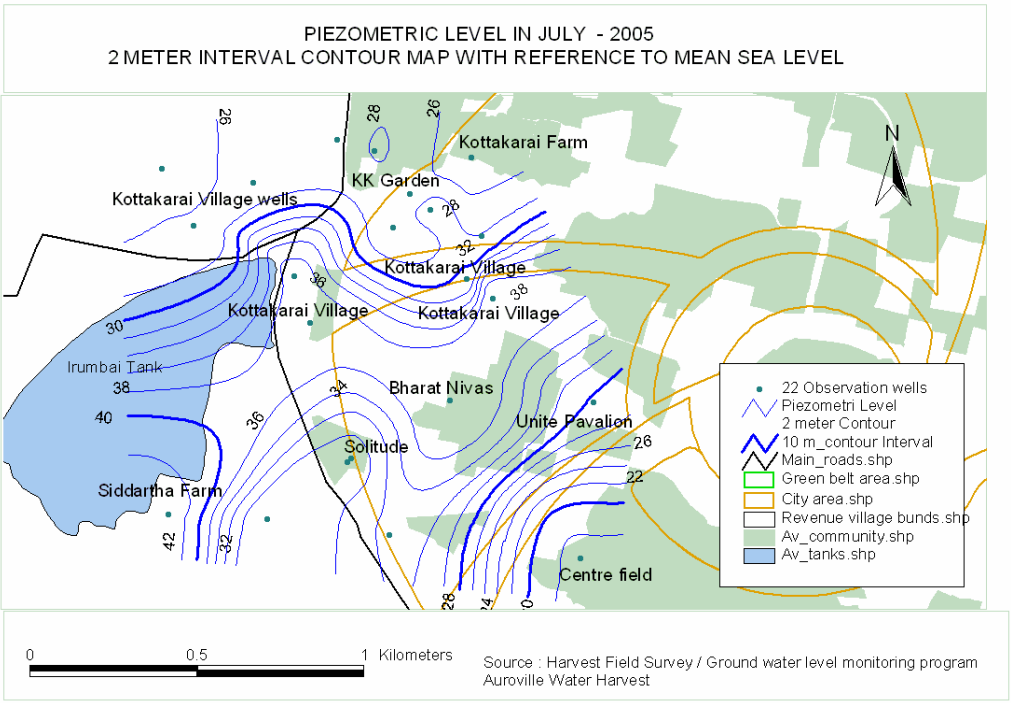
Groundwater movement is generally studied conventionally by the data of hydraulic gradients and aquifer parameters estimated using pumping tests. Velocity of groundwater is generally calculated along the flow direction using Darcy's law V=K dh/dl where V is the velocity of groundwater, K is permeability and dh/dl is hydraulic gradient.

7.1. Interconnection between Aquifers

Interconnections between different aquifers play a major role in the groundwater development. In the present investigation, this aspect has been studied in detail using water level data from piezometers installed at the same site but in different aquifers. e.g. Cuddalore sandstone, Manaveli and Kadaperikuppam lime stone formations.

7.2. Depth to Water Level

Presently, there are 22 observation wells (Abandoned wells) in the International zone area being monitored continuously for measuring the water level by Harvest ground water team. Data on water level are being compared with the monthly rainfall of the year in order to see the impact of rainfall in the aquifers. Like wise hydrograph has been prepared with water level and rainfall for each well. The minimum water level of 41.49m bmsl (below mean sea level) was observed in our study area during the year 2005, and average water level is 30.55m. The seasonal change in the water level varies from 4m to 6m.The water level is showing a declining trend to 41.49 m bgl during July 2005.



According to our study area we can describe the four main exploited aquifers, which are as follows.

a) The Cuddalore sandstone aquifer

This is the most potential aquifer in the investigated area and occupies approximately an area of 115 sq km as outcrop and about 375 sq km underlies below the alluvial deposits, but auroville area is having the Manaveli clay. This formation mainly consists of 80% granular zones consisting of sands, sandstone, gravel etc. Groundwater occurs under unconfined, semi-confined and also at some places under confined conditions. In the southeast portion of Pondicherry region, a seasonally flowing well at Krishnapuram is located. Recharge to this aquifer occurs by direct infiltration and percolation within the outcrop area and also through leakage from the alluvial deposits.

In Auroville area Tertiary formation of sandstone that is unconformable with the other sedimentary beds. They have been eroded or they have not deposited in the middle of the sedimentary basin. This unconfined aquifer is a moderate quality of reservoir. Its exploitation is made through open well with large diameter, 4 to 6m. Water electrical conductivity range between 385 to 875 microsimens / centimeters near the Kaluvelly swamps. Its potential reserves are limited.

Natural flow goes from NW to SE with a hydraulic gradient from 7 to 28.5m in the study, which was done in 1948. Transmissivity and field permeability of the aquifer ranges from 420 to 600 m²/day respectively, as cannot be seen in the western portion. Moreover, at present the trend of the water flow is moving to the direction of SW. In the eastern and central portion thickness of the formation is more. Because of its large thickness and favorable aquifer parameters this formation is the most potential aquifer for the groundwater development.

b) The Kataperikuppam formation

It is essentially calcareous sandstone, yellowish to dirty white in colour. It also comprises thin lenses of clay and shale and bands of shell limestone. No data about thickness is available at outcrop area. Transmissivity and field permeability of the aquifer ranges from 320 to 460 m^2/day.

c) Ottai clay stone formation

It is outcropping relatively in larger area than other cretaceous sediments; covering the villages Ottai, Pullichapallam and Ravuthankuppam. It is mainly black to greenish gray clay stone with a few bands of calcareous and micaceous siltstone. Thinning of the formation at Auroville and further at Kalapet and absence of top most formation of upper cretaceous called Thuruvai limestone is the indicative of tectonic disturbance accompanied by Unconformity. The total thickness of this formation in the southern side is not known. Transmissivity and field permeability of the aquifer ranges from 60 to 70 m^2/day

d) The Vanur sandstone aquifer

Unconfined at the vanur sandstone outcrop, it becomes ottai clays. Because of good hydrodynamic properties (Transmisivity between 250 m^2 and 800 m^2 1948). This aquifer was a reservoir of high quality and adequate quantity of water potential for several years.

Natural flow goes from NW to SE with a hydraulic gradient from 7 to 35.7m in the study was done in 1948. The intensive drilling of deep wells equipped with electric or diesel pump (Depth can reach 100m to 450m) has drastically modified the flow and the aquifer is withdrawn at a rate exceeding the recharge one. Waters of the Vanur sandstone aquifer show varying electrical conductivity from 950 microsimens / centimeters to 1750 microsimens / centimeters related to space and related to time depending on climatic conditions and pumping rate. This aquifer could be in hydraulic connection with: 1.Sea water of the Bay of Bengal; 2.saltwater of the Kaluvelly swamps (2700 to 4500 microsimens / centimeters) .3. Waters of the Ramanathapuram aquifer underlying, which are not used because of sulphide content and 4. Waters from the charnokite aquifer could be involved, aquifer underlying the Ramamnathapuram sandstone.

7.3. Occurrence of Groundwater

In the study area, groundwater generally occurres in the intergranular pore space of the sandstone. It also occurs in the fractures of the hard and compact limestone's. These area mainly occupied by the sedimentary formations underlined by the crystal lined basement. Groundwater occurs in the area of both under unconfined and confined conditions in the sandstone and limestone aquifers. The sandstones of the cuddalore formation (Territory) sandstone. And Kadaperikuppam, Vanur and Ramanathapuram sandstone (Cretaceous) formation constitute the potential aquifers of this area. Though some granular zones exist in the manaveli and ottai formation (Cretaceous) they may not form promising aquifers due to their limited aerial extent and poor permeability but may yield meager quantities of water due to leakage from other aquifers. Hence Manaveli and Ottai formations act mainly as aquitards.

8. GROUNDWATER LEVEL FLUCTUATION

What emerge out of the research is on one hand the clear difference between the Cuddalore formation and the following ones, with a flow from West to East and a much lower water level for the Cuddalore , and on the other hand **the connectivity and opposite flow** (East to West) of Manaveli and Kadaperikuppam, with high water level.

Accordingly, and in regard to water level difference between this 2 systems, Cuddalore is not included in this part of the research as it is of no significance in addressing the water potential and risks for the International Zone.

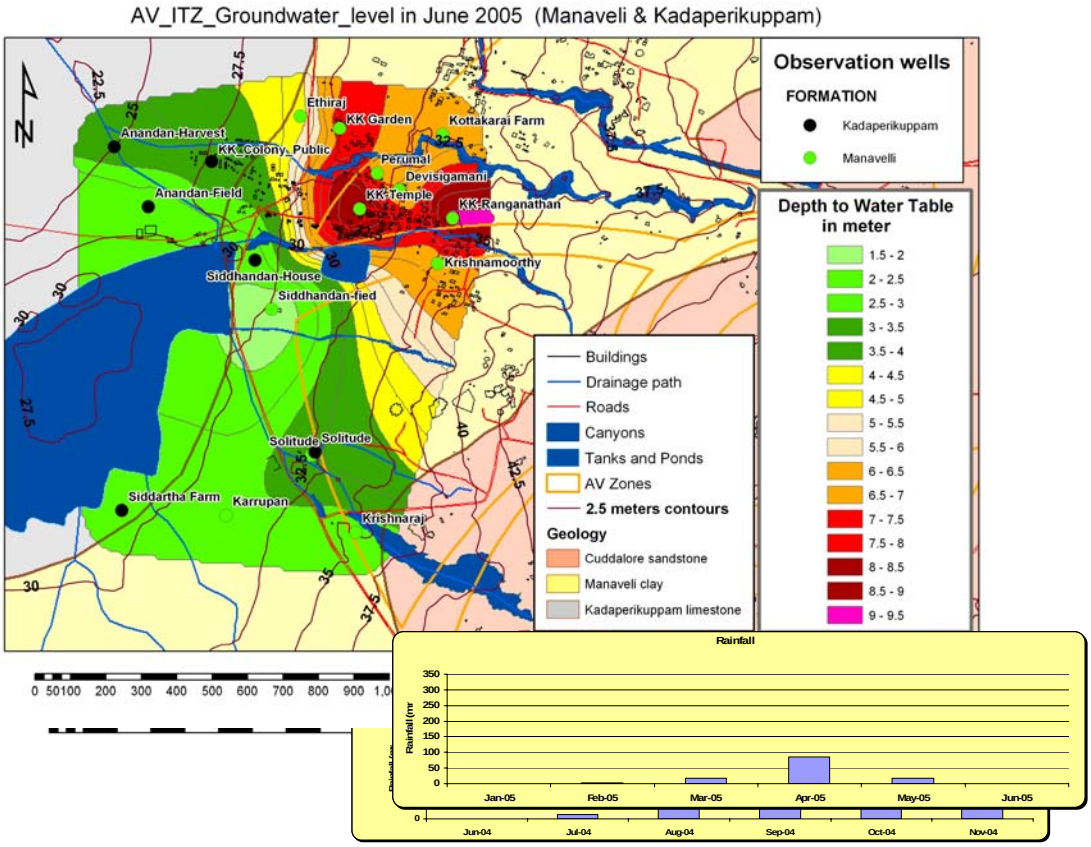
8.1. Methodology

- Usage assessment of wells
- Selection of open wells and borewells for monitoring purpose by aquifer systems: Manaveli and Kadaperikuppam
- Monthly groundwater level monitoring of 18 wells (12 on Manaveli and 6 on Kadaperikuppam) from May 2004 to January 2006 (January, march and august 2005 are missing). No observation wells exist on the eastern part of the Manaveli formation.
- Data processing and analyses in regard to geological formation and rainfall pattern
- Generation of graphs per well. At this stage 5 wells has been disregarded because of the lack of coherence of data or other factors. For example Bharat Nivas open well data set is clearly showing that the well is clogged and need to be cleaned.
- GIS integration
- Contour map generation with reference to topographic contour, salient features existing on the ground (canyons & drains, water bodies, roads, buildings, outcropping geological setup), planned main features (delineation of zones) and rainfall pattern

8.2. Water level fluctuation in comparison to ground level

As per WHO researches, **contaminants from raw water discharge point will contaminate laterally 10 meters away, and vertically 3 meters away**, providing soil is homogeneous and of appropriate structure. Moreover, consideration must be taken for the water column in the unsaturated part of the soil during the monsoon which can create temporarily direct connection to the water table. Accordingly, no unprocessed or poorly processed wastewater must be discharged in areas where the water table can reach 3 meters below ground level, or areas getting flooded temporarily during rainfalls.

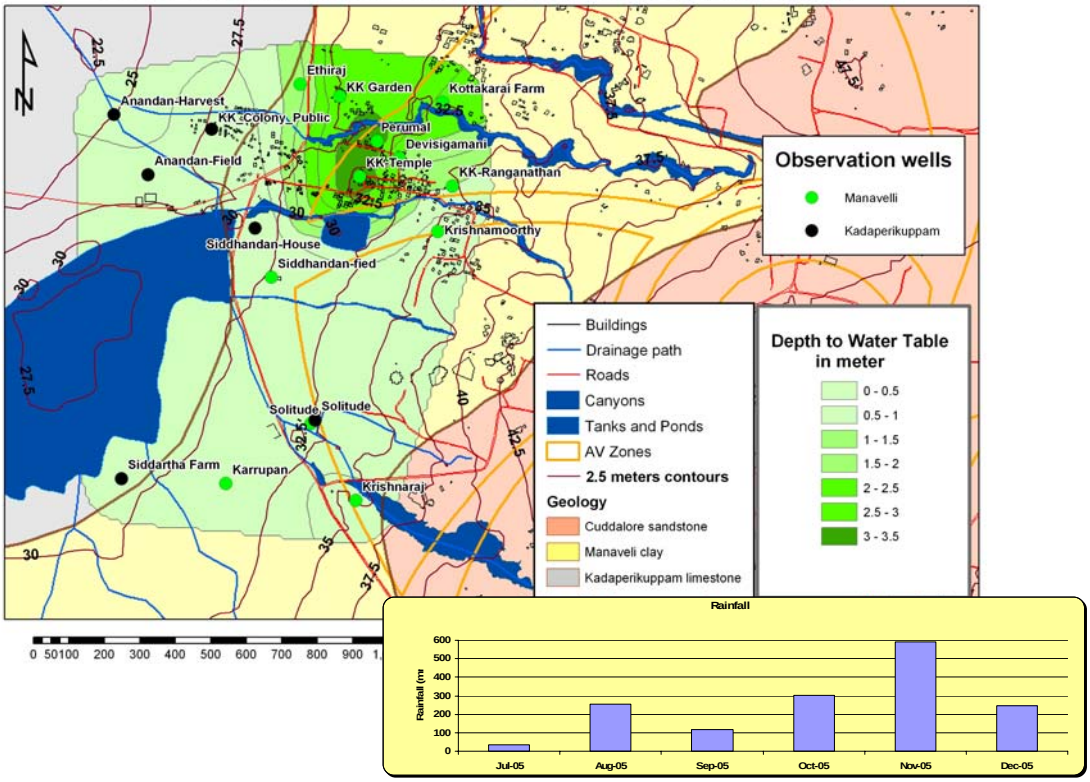
This is also bringing concern for storm water control coming from roads and parking areas because of the spillover from motorized vehicles.



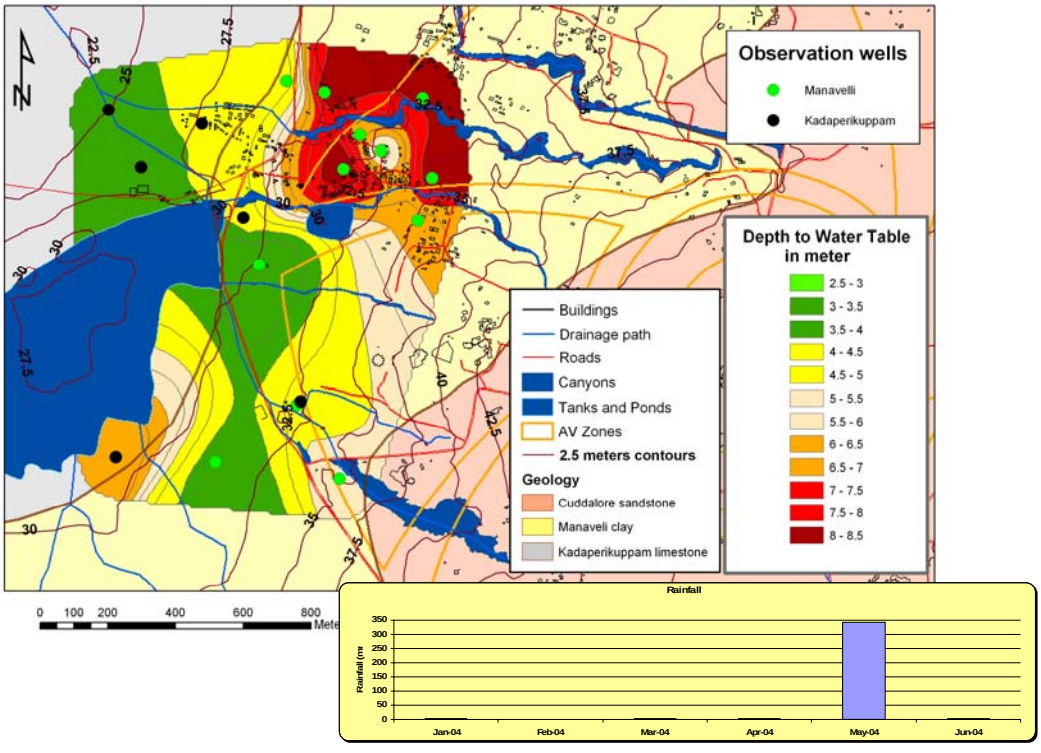
The maps below include the rainfall pattern for the six preceding months.

The ground water level from the surface is fluctuating from 9 meters to 0 meters over the area and over time.

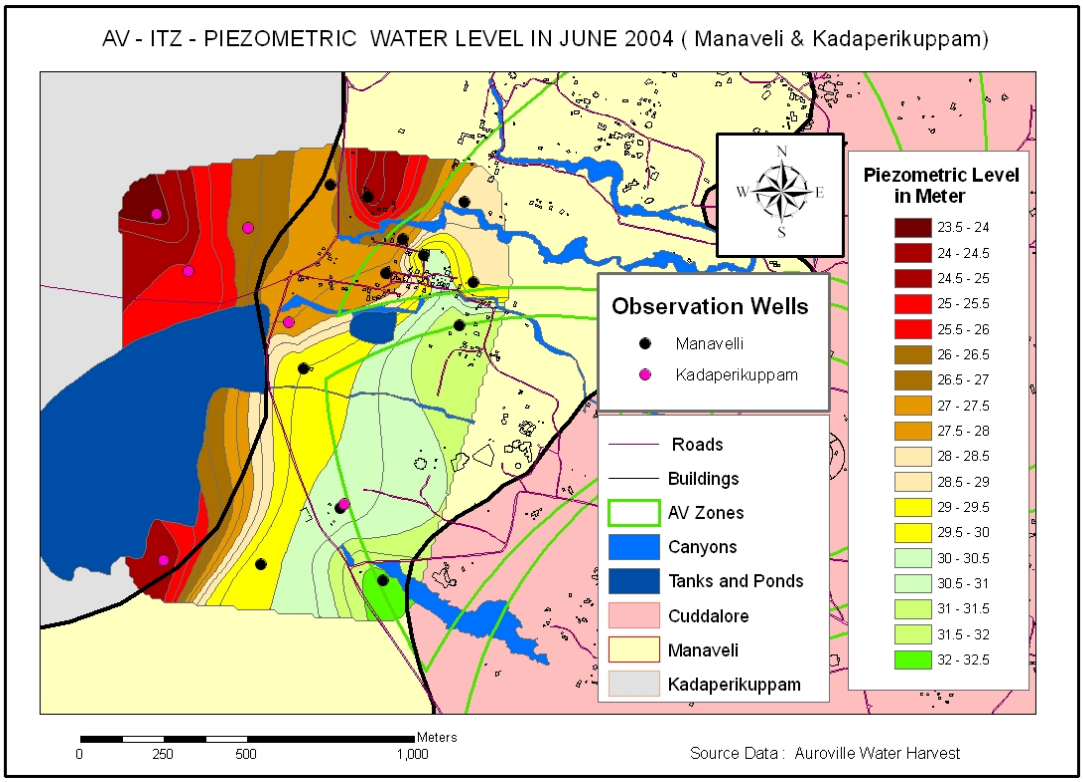
AV_ITZ_Groundwater_level in December 2005 (Manaveli & Kadaperikuppam)

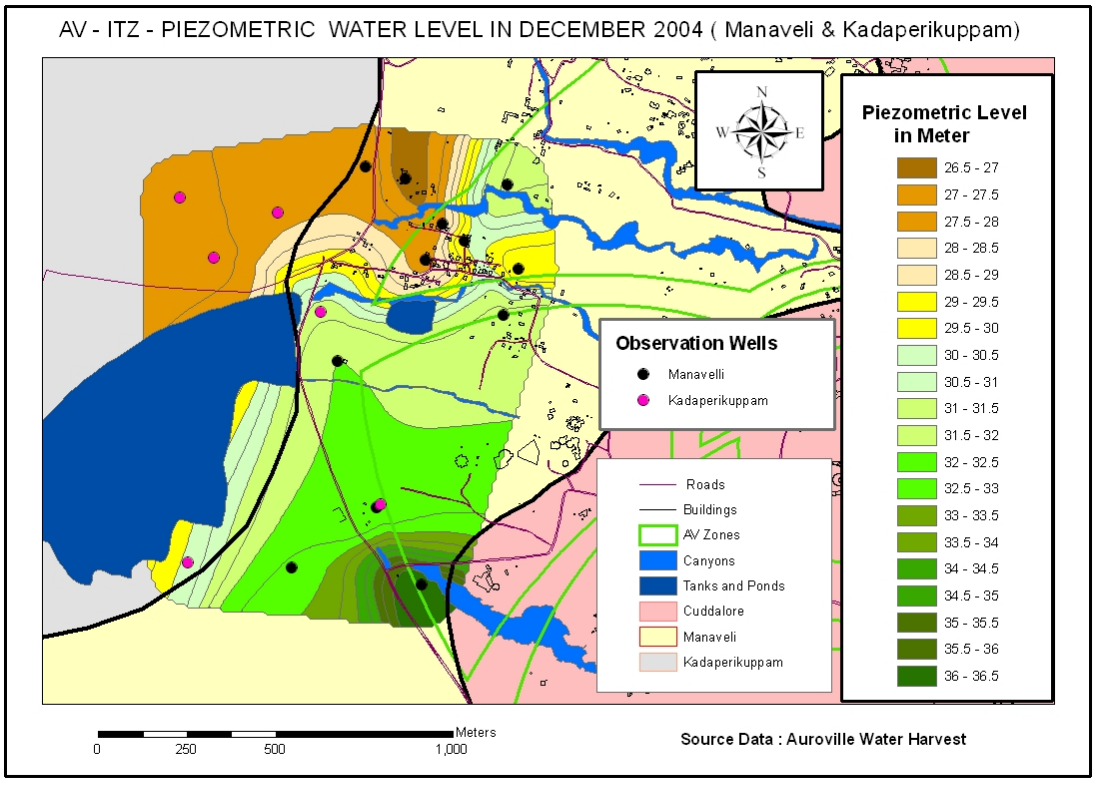


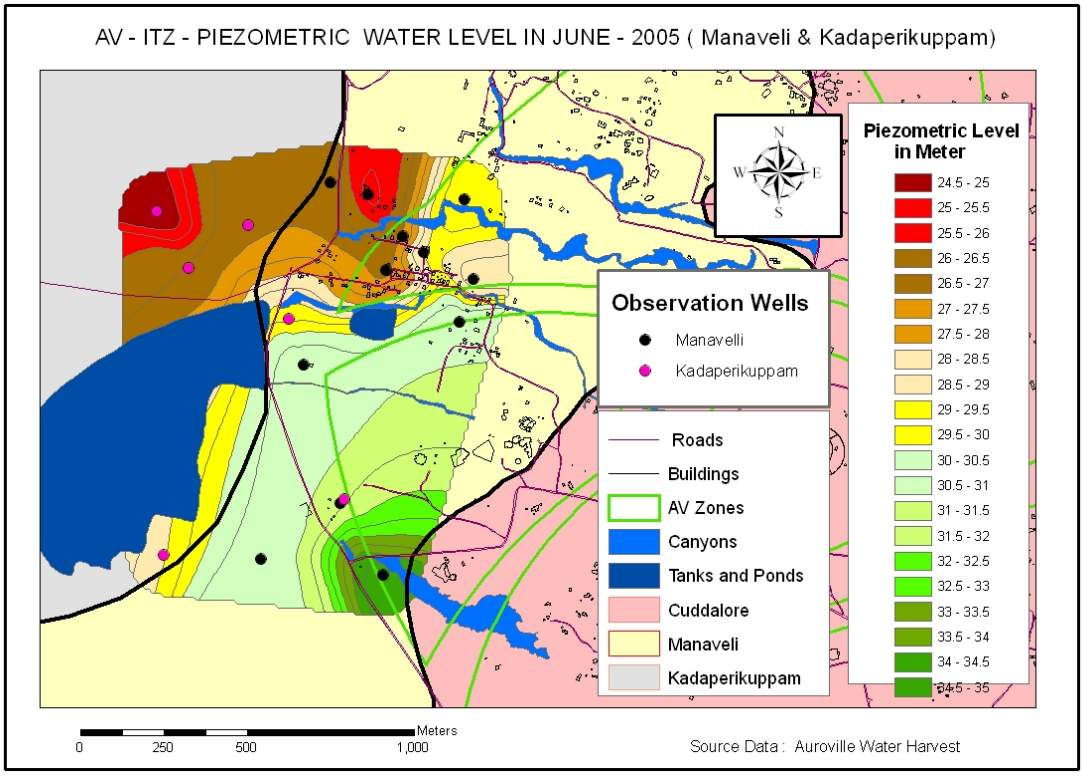
AV_ITZ_Groundwater_level in JUNE 2004 (Manaveli & Kadaperikuppam)

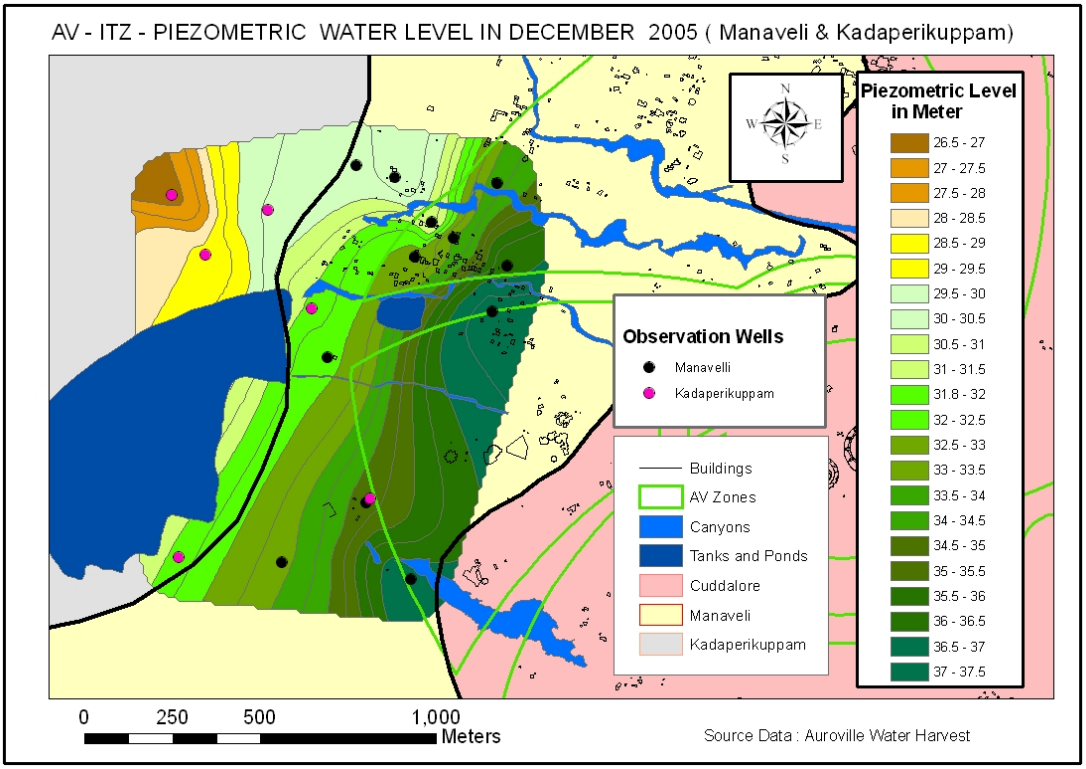


8.3. Water level fluctuation in comparison to Main Sea Level (MSL)






AV - ITZ - PIEZOMETRIC WATER LEVEL IN JUNE - 2005 (Manaveli & Kadaperikuppam)
Piezometric Level in Meter
24.5 - 25
25 - 25.5
25.5 - 26
26 - 26.5
26.5 - 27
27 - 27.5
27.5 - 28
28 - 28.5
28.5 - 29
29 - 29.5
29.5 - 30
30 - 30.5
30.5 - 31
31 - 31.5
31.5 - 32
32 - 32.5
32.5 - 33
33 - 33.5
33.5 - 34
34 - 34.5
34.5 - 35
Observation Wells
Manavelli
Kadaperikuppam
Roads
Buildings
AV Zones
Canyons
Tanks and Ponds
Cuddalore
Manaveli
Kadaperikuppam
N
W
E
S
0
250
500
1,000
Meters
Source Data : Auroville Water Harvest


AV - ITZ - PIEZOMETRIC WATER LEVEL IN DECEMBER 2005 (Manaveli & Kadaperikuppam)
Piezometric Level in Meter
26.5 - 27
27 - 27.5
27.5 - 28
28 - 28.5
28.5 - 29
29 - 29.5
29.5 - 30
30 - 30.5
30.5 - 31
31 - 31.5
31.8 - 32
32 - 32.5
32.5 - 33
33 - 33.5
33.5 - 34
34 - 34.5
34.5 - 35
35 - 35.5
35.5 - 36
36 - 36.5
36.5 - 37
37 - 37.5
Observation Wells
Manavelli
Kadaperikuppam
Buildings
AV Zones
Canyons
Tanks and Ponds
Cuddalore
Manaveli
Kadaperikuppam
N
W
E
S
0
250
500
1,000
Meters
Source Data : Auroville Water Harvest

8.4. Conclusion

- There is **no tangible difference of reactivity between the Manaveli formation and the Kadaperikuppam formation**. This is indicating that **the Manaveli formation is not acting as a vertical barrier** (Aquiclude), in accordance with National Geophysical Research Institute publication of June 1987. It must be noted that if similar situation prevail below the Cuddalore formation, as other information are indicating, the only way to manage the ground water resources for Auroville in a coherent way is by including the geological setup from the surface to Ottai Clay formation (4 formation from the surface). This means that a minimum area of about 70kms with its activities and population has to be included in any appropriate approach for sustainable water management for Auroville.
- From the above maps we can conclude that **the western part of the International Zone shows a high water table all over the year**.
- **The entire area has a water table level at or very close to the surface for months**. For 2005-06, the water level was at less than 1 meter from the surface, at least from November to February. The water table can hence be fully saturated at time.
- **Consequently, very strict regulation and physical control should be applied to protect the water table contamination from wastewater, leaching of solid waste, spill over of motors etc.**
- **Percolation ponds and other recharge structures** can favorably be developed, starting from Matrimandir vicinity down to the city limit (Ayarpadi area or solitude community. It will improve the groundwater available through the year as well as the quality of IZ region.
- Extraction in the International Zone area (including the village and the extends) must be strictly control and the construction of new wells must be limited and planed.
- **Contour bunding** developed all along the slope in accordance with the nature feature and the general layout will develop a very pleasant yet very environmentally sound environment

9. GEOPHYSICAL SURVEYS

9.1. Objectives

Geophysical studies comprising electrical resistivity surveys and nuclear and electrical logging of boreholes have been made in the Auroville area with the following objectives

i) Delineate the aquifers occurring at shallow and deeper horizons and demarcate their lateral extents

ii) estimate the quality of formational water

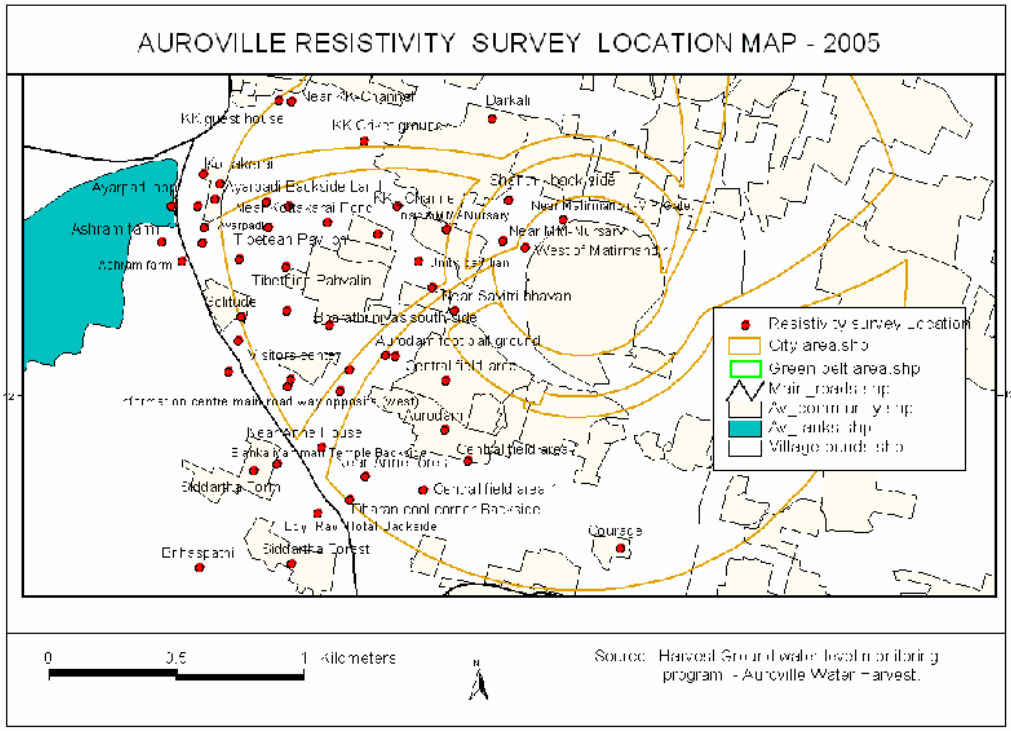
iii) determine the nature and extent of different sub-surface geological formations

iv) delineate the basement configuration

9.2. Electrical Resistivity Survey

The field survey was started on 05/05/2005. According to the plan of action the field survey work of Resistivity survey has been conducted in the International Zone of Auroville at different locations. The resistivity survey was conducted in 53 locations as per the proposal.

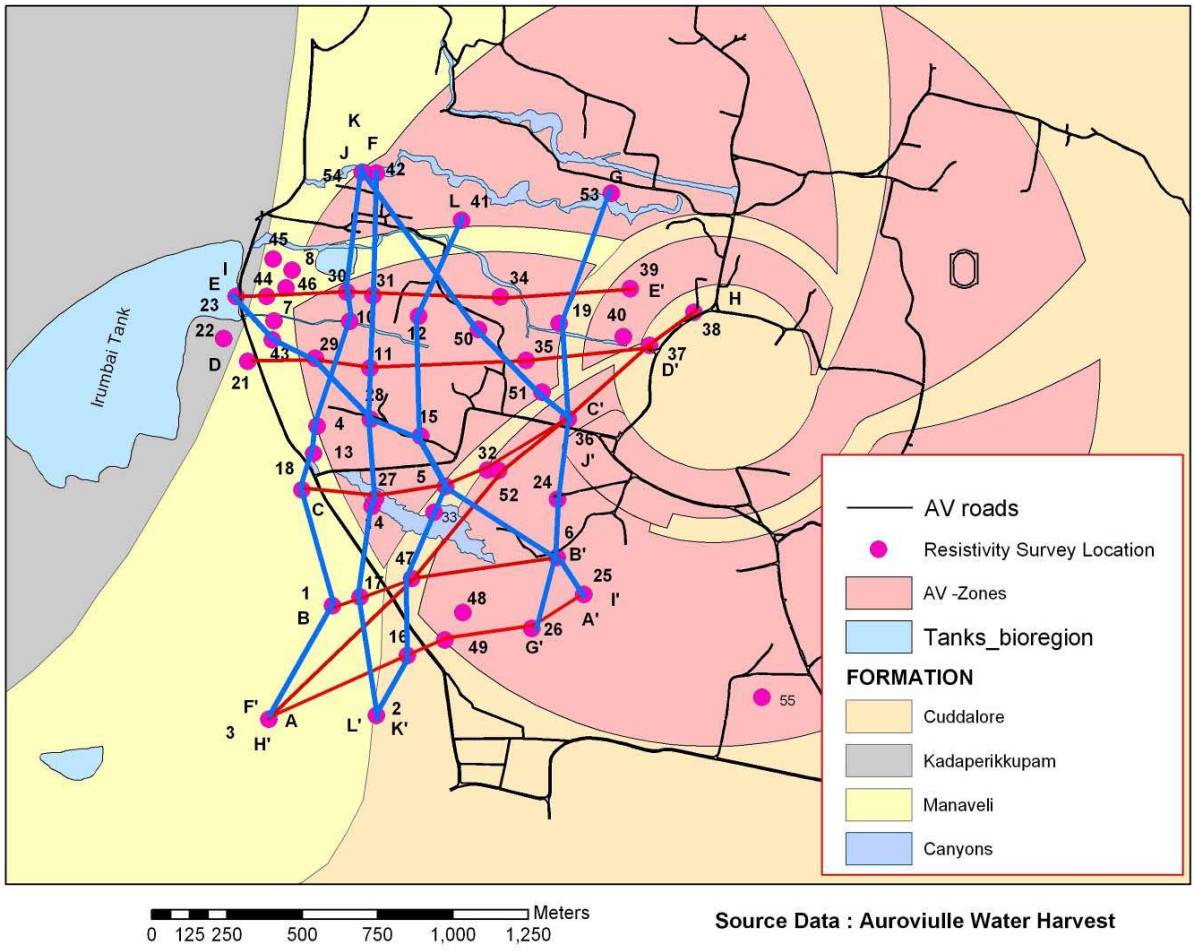
We carried out electrical resistivity and seismic refraction surveys in the area for ground water investigations and for delineating the basement configuration. Since the resistivity survey conducted was of shallow depth range, precise data on the nature of formations of greater depth could not be obtained. Hence they concluded that the possibility of ground water development has to be restricted within 120 m. However, further exploration by drilling coupled with the geophysical surveys have brought to light the occurrence of moderate potential of aquifers even beneath 450 m down to the crystalline basement.



9.3. Cross section analyses

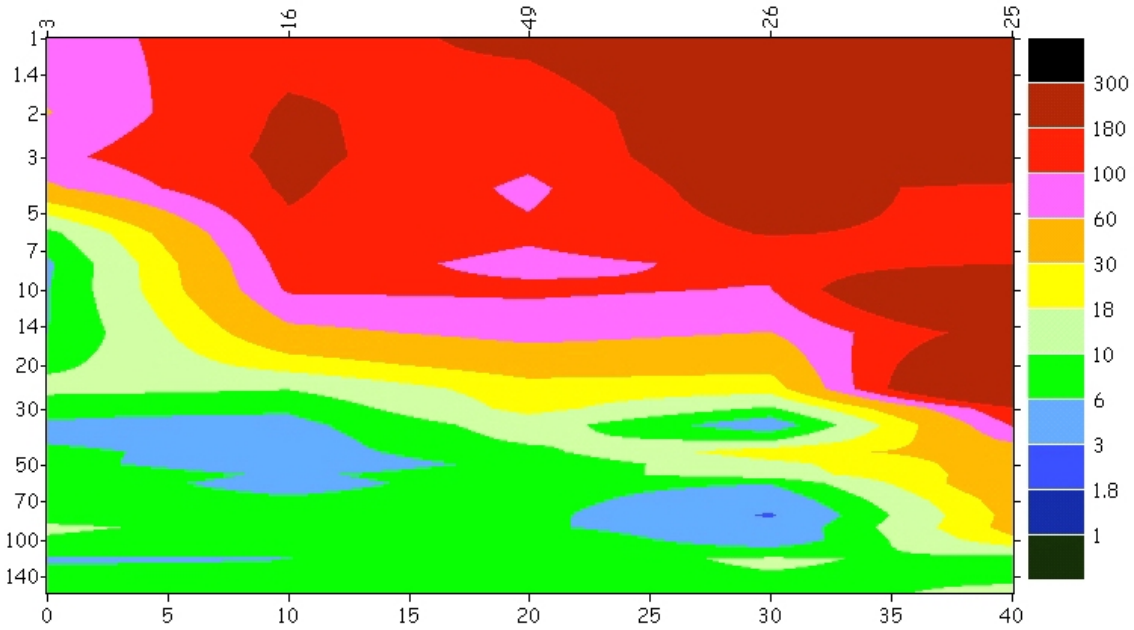
Deep electrical resistivity surveys employing vertical electrical soundings (VES) at 53 sites were carried out with D.C. resistivity meter (DDR3). The Schlumberger configuration of electrodes with a maximum spread (AB/2- - half of the distance between the current electrodes) of 160 m has been adopted. The Cross section obtained from the present deep electrical resistivity surveys show multiplayer sub-surface geo-electrical section. The occurrence of the VES Curves with steep descending trend is due to the presence of highly resisitivity surface layer.

INTERNATIONAL ZONE VES - LOCATION AND CROSS SECTION MAP - 2005

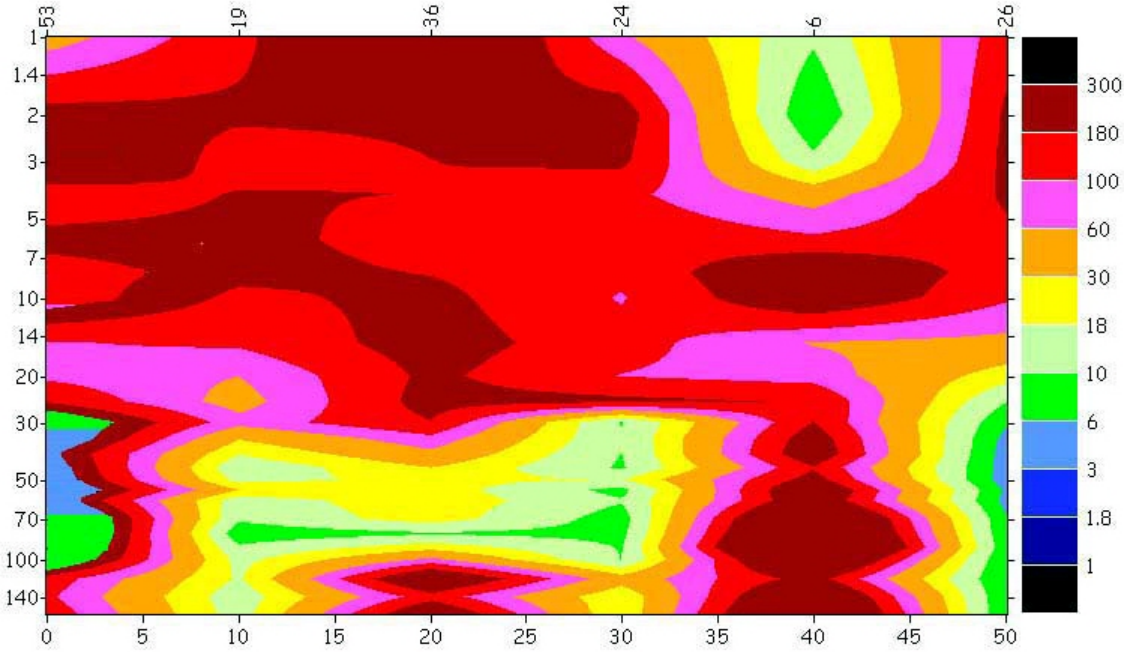


Source Data : Auroviulle Water Harvest

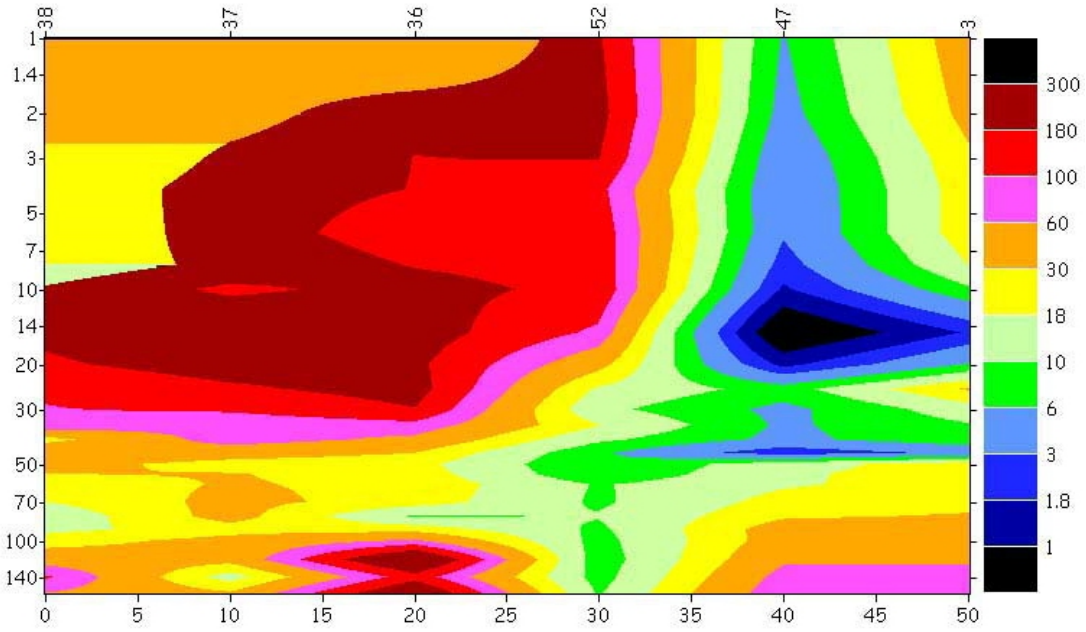
The following section (A-A') is taken from SW – NE direction. This section is clearly indicating the limit of the territory formation with the help of the resistivity values. The resistance of the Cuddalore sandstone is usually more than 10 ohm mt. But in our area it shows 60 to 300 ohm mt with a clearly indicated unsaturated zone (Dry portion) to a depth of about 15 mt. The continuity of the high resistance shows that it is a good recharge area as well. Apart from that the resistance of the formation is from 6 to 30 ohm mt, which reveal good extraction potential for our region.



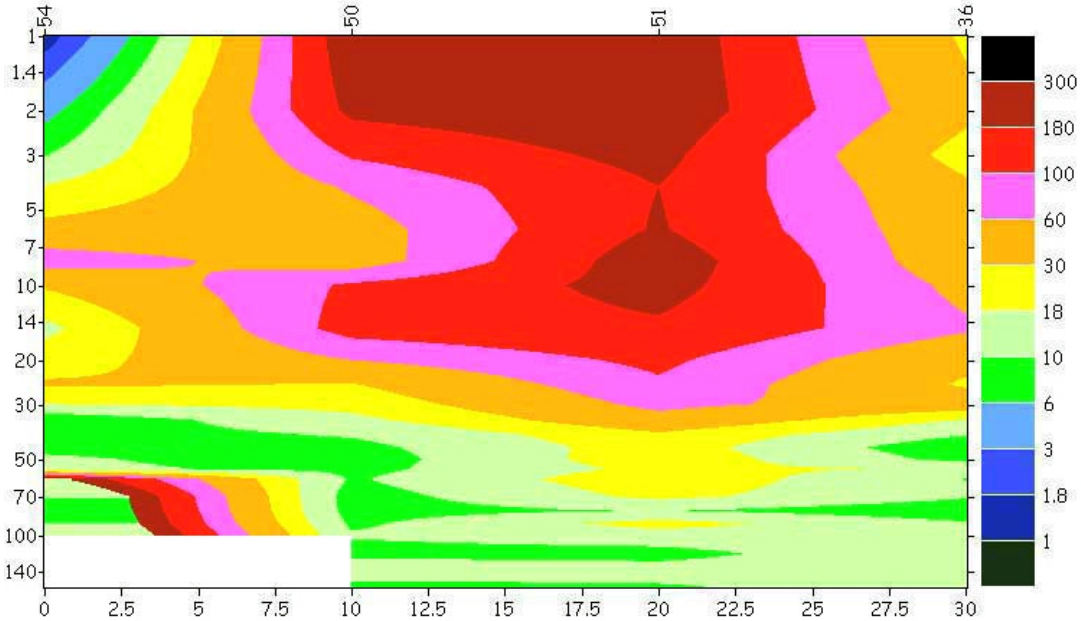
The following section (G-G') is taken from N –S direction. This section is clearly indicating a very good extraction potential zone until 140 mt and deeper. Most of the locations show values above 100 ohm mt indicating unsaturated zone and good recharge potential.



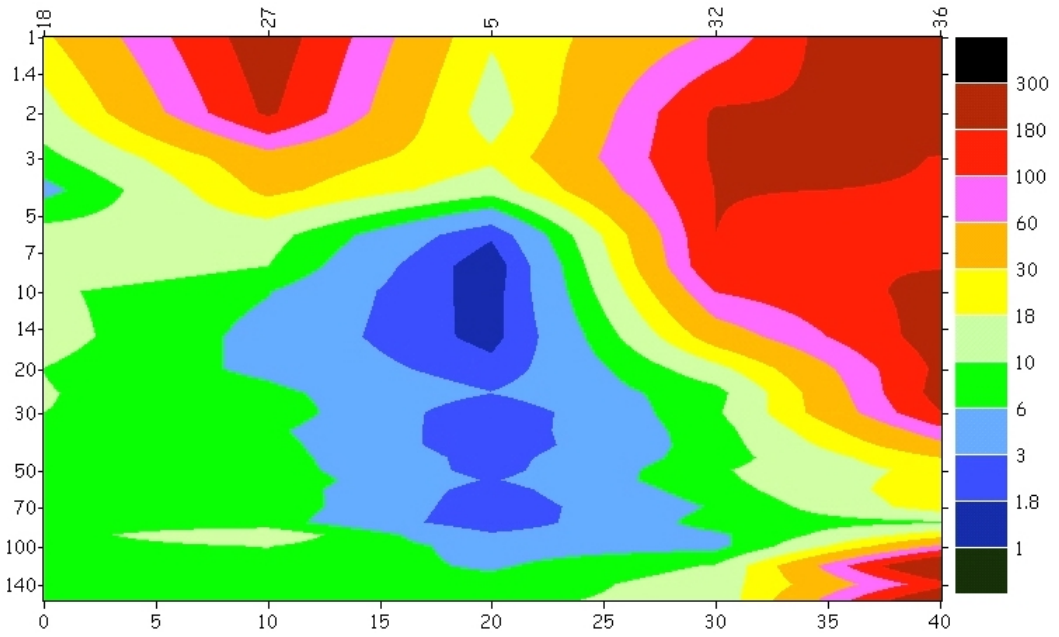
The following section (H-H') is taken from SW –NE directions. This section is indicating the limits between formations, with points no 3 and 47 falling in the Manaveli formation. But the water potential is not satisfactory, so the resistivity values is less i.e. 3 to 8 ohm mt. The rest of the locations are falling in the Cuddalore sandstone. The resistance of the Cuddalore sandstone is more than 10 ohm mt but the water potential is satisfactory.



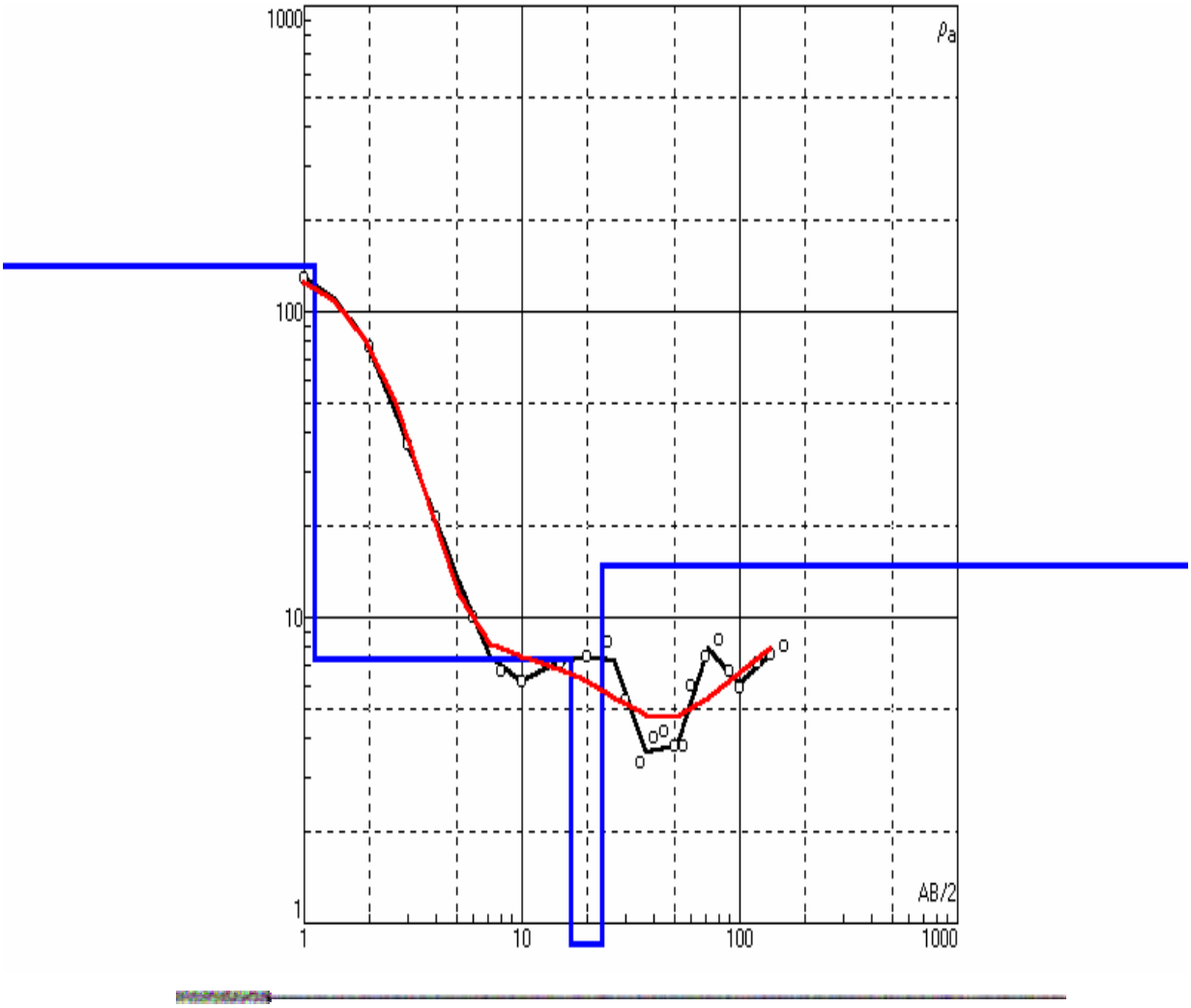
The following section (J-J') is taken from NW –S E directions through the International Zone. This section is clearly showing the formations limit with location no 50, 51 and 36 falling in the Cuddalore sandstone. Apart from that the NW part is falling in the Manaveli formations. But the water potential is not fitting with satisfactory yield, while the SE part shows a satisfactory yield.



The following section (C-C') is taken from W – E directions, the location no 27 and 32 to 36 are separated by two small barriers. The resistance of the Cuddalore sandstone visible on the right part of the section shows values between 60 to 300 ohm mt clearly indicating an unsaturated zone (dry portion) up to a depth of 15 mt. Moreover it is a showing good recharge potential. Apart from that the resistance of the formation is 6 to 30 ohm mt a good potential zone of our region.



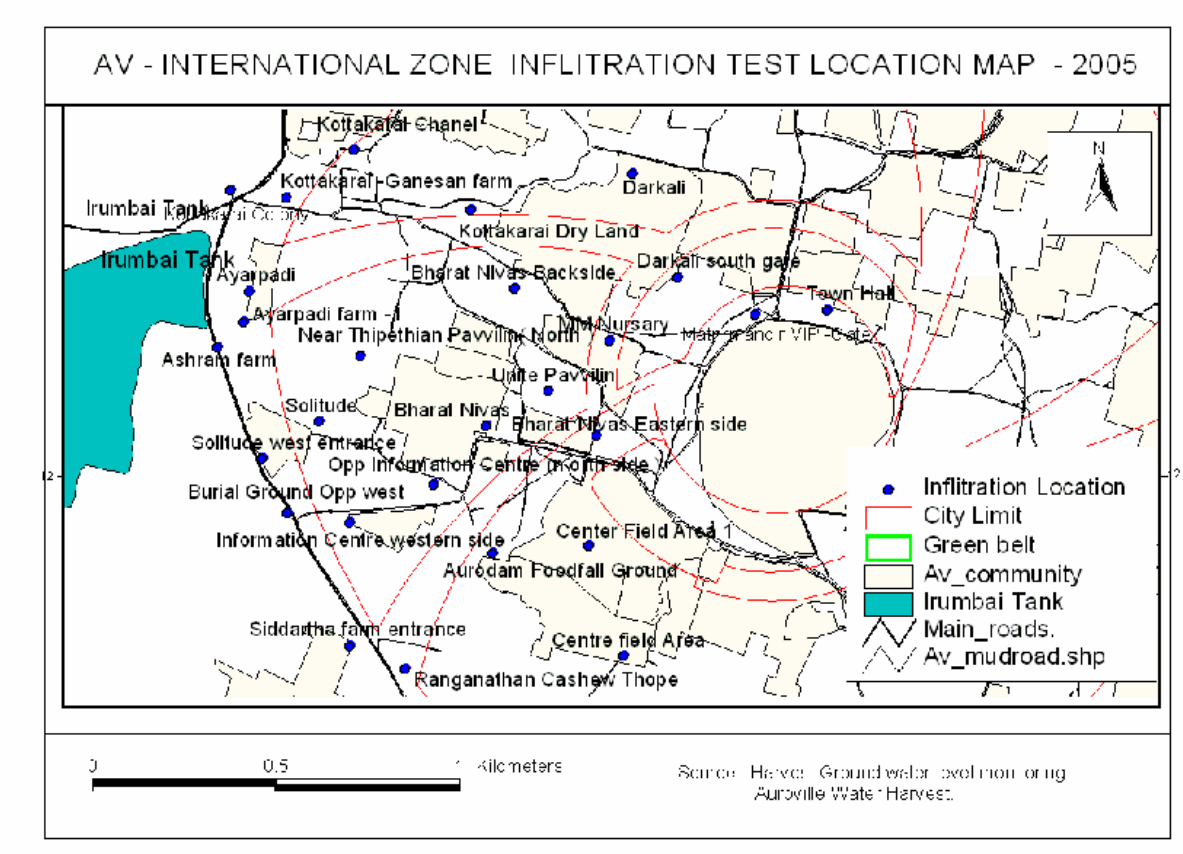
The following graph made using inverse slope method of calculation is depicting the sub-surface of soils, which is to find out the levels of the layers of the sub surface soils. Particularly this graph shows three layers with a total depth of 21.20m.



10. INFILTRATION TEST

Most of the people commonly use the method to determine infiltrations is to flood an area contained within a bund, and to record the water level over a period of time (Ponded method).

The measured infiltration rate is markedly affected by cylinder diameter, the rate measured being lower for larger diameters because of the reduced effect of lateral flow. Better estimates are therefore obtained if two concentric rings are used, the water level maintained in the both, while measurements are made in the inner; this compensates lateral flow.



10.1. Procedure

1. Pre wet the area by soaking for a few hours using an earth bund to contain the water.

2. Two rings, inner 30cm diameter, outer 60cm diameter, height 50cm are required for the experiment. Vertically drive these two rings to about 15 cm in to the wet soil so the smaller ring is centered in the larger.

3. Fill both the cylinders to about 15cm of water, record the time and the distance from the water level in the inner cylinder top.

4. Measure the water level at 1, 5,10,20,30,45,60,90 and 120 minutes or more frequently if infiltration is rapid.

5. Refill the cylinder when the level has dropped to about 10cm. Note the water level before and after refilling on each occasion. Try to maintain equivalent water levels in the inner and outer rings.

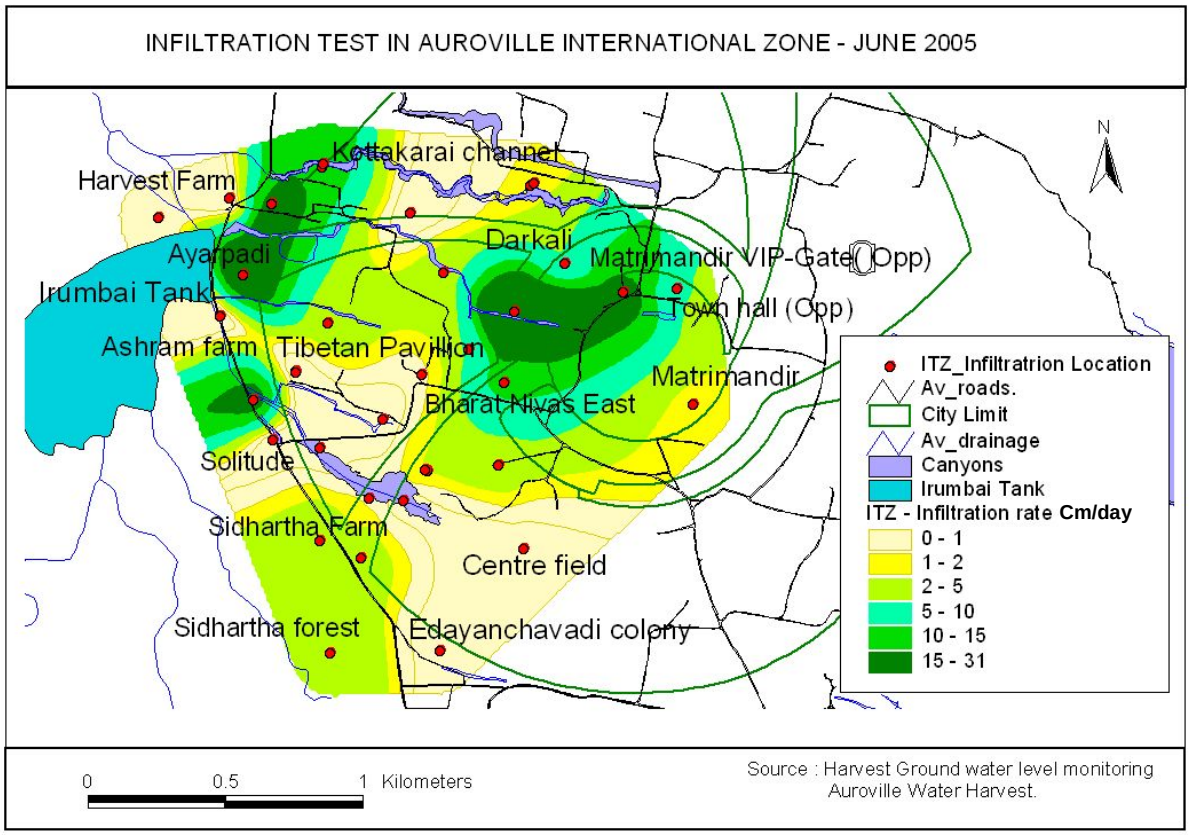
6. Continue measurements until a steady state has been reached.

7. Construct a table of results to show time intervals (min), Cumulative time (min), intake (cm), Cumulative intake (cm) and infiltration rate (cm / hr)

8. Plot infiltration rate (cm/hr) against cumulative time (min)

Note: The basic infiltration rate (cm/min) is that when study state (i.e. a straight line on the graph is attain)

The infiltration test was started on 13.06.05 to 02.07.05. According to the plan of action, the field survey has been conducted in the International Zone of Auroville at 28 different locations.



10.2. Computation of rate of infiltration

The observed data had been provided, in which the output file of the computer program provided in the rate of infiltration can either be determined by Horton's formula or Kostiakov's equation. In our present study, we have used Kostiakov's equation. The detailed findings of the field study of the Infiltration test are given below.

The following table shows the rate of infiltration as well as the location of our study area.

These tests has been carried during June 2005 to ensure that the soil is dry and that the water level is at the lowest.

ID	Location name	Soil Type	Geology	IFR Cm /h
1	Ashram farm	Compact Sandy loam soil	Manaveli	0.12
2	Aurodam football ground	Red soil	Cuddalore	3.00
3	Ayarpadi	Compact Sandy loam soil	Manaveli	24.00
4	Bharat Nivas	Compact red soil	Cuddalore	1.80
5	Bharat Nivas back side (North)	Compact red soil	Cuddalore	4.20
6	Bharat Nivas East	Compact red soil	Cuddalore	12.20
7	Centre field area	Compact red soil	Cuddalore	0.36
8	Centre field area -1	Compact Sandy loam soil	Cuddalore	4.12
9	Close to the Tibetian Pavilion	Compact Sandy loam soil	Manaveli	4.08
10	Darkali	Compact lateritic sand stone	Cuddalore	2.40
11	Darkali south gate	Compact red soil	Cuddalore	6.30
12	Edayanchavadi colony	Compact Sandy loam soil	Cuddalore	0.30
13	I-M-center Opp side	Compact Sandy loam soil	Manaveli	0.42
14	I-M-Centre west-Burial Ground	Compact Sandy loam soil	Manaveli	0.30
15	Information center west side	Compact red soil	Cuddalore	0.04
16	Kottakarai channel	Compact Sandy loam soil	Manaveli	14.40
17	Kottakarai colony	Compact Sandy loam soil	Manaveli	0.12
18	Kottakarai dry land	Compact Sandy loam soil	Manaveli	0.20
19	Kottakarai Ganesan farm	Compact Sandy loam soil	Manaveli	18.00
20	Matrimandir Nursery	Compact Sandy loam soil	Cuddalore	30.36
21	Matrimandir VIP-Gate (Opp)	Compact Sandy loam soil	Cuddalore	18.30
22	Ranganathan Cashew field	Compact Sandy loam soil	Manaveli	4.20
23	Sidhartha Farm Entrance	Compact Sandy loam soil	Manaveli	4.04
24	Solitude	Clay soil	Manaveli	0.30
25	Solitude west Entrance Gate	Compact Sandy loam soil	Manaveli	18.00
26	Town hall (Opp)	Compact Sandy loam soil	Cuddalore	6.18
27	Unity Pavilion	Compact Sandy loam soil	Cuddalore	6.48
28	Barathinivas South	Compact Sandy loam soil	Manaveli	1.85

In order to calibrate the results in regard to saturated soil, one extra est has been carried out in Matrimandir VIP-Gate (Opp) (ref 21) the 23rd of December 2005, in fully saturated condition. The results show a value of 5.04cm/h, which is still very high in such context.

10.3. Conclusion

- **The average infiltration is around 6cm per hour**, a good value.
- Generally speaking, the rate of **infiltration is good** on a large part of the International Zone, apart of an area starting in Center Field, through Aurodam and until the Tibetan Pavilion, showing a low infiltration capacity.
- Kottakarai village canyon and is surrounding is showing a very good infiltration rate, which is indicating as well a **direct communication from the surface to the 2nd and may be the 3rd aquifer**.
- In contradiction with expectation and earlier observation, the Aurodam canyon is showing a rather low infiltration capacity. This is due to the important siltation taking place here. It must anyhow not be misjudge as a low risk area as this phenomena is superficial and in this particular case does not reflect the reality of the geological structure underneath.
- The **maximum rate of infiltration is found in the Matrimandir office/ Nursery area, around the Ashram farm and at the bottom of Kottakarai village** and ranged from 15 to 30 cm/h.
- Practically, the area from north of Matrimandir until Kottakarai lowest end is showing very good infiltration rate, which should be preserve and used for ground water recharge. It must be noted that the former fall on the Cuddalore sandstone formation while the latest is on the Manaveli formation. **It is very important to integrate artificial recharge features in the development of this particular area**. This will help to recharge both systems and maintain the water level in order to ensure sustainability. Devices like percolation pond, low laying vegetated area, etc should be fully part of the landscaping in this zone.

10.4. Traditional water storage and drainage systems.

A long–term plan for the Irumbai tank includes bringing back the traditional rainwater drainage system. This system utilized a network of Eris and channels to irrigate the fields. It is then flowing downstream to a chain of tank up to Kaluvelly swamp, connecting Auroville to its bioregion. It needs regular maintenance and understanding than people get aware of water availability and potential use. Due to various political choices through time such tanks have been neglected. After a while the system deteriorated due to lack of maintenance. It is anyhow a wonderful asset for Auroville which cannot be disregarded. Reutilization and optimisation of this system would be very beneficial, especially when looking at the current increase of groundwater extraction.

10.5. Conclusions

The maximum rate of infiltration is found in the Mathirmandir Nursery area ranging from 20 to 30%, which is falling in the Cuddalore sandstone formation and also we can use as the Recharge zone. More over this zone water level trend is declined, the water flow direction moving towards western side of the bioregion. So it is better to take up an artificial recharge program in the particular zone, which will help us to maintain the same water level for the sustainability. E.g. To creates a percolation pond in this zone.

11. GENERAL CONCLUSION AND RECOMMENDATIONS

11.1. General Conclusion

The International Zone of Auroville is largely seating on a shallow aquifer where mixed sand and clay are predominant.

During a good part of the year the water level is close to the surface on the western half of the zone at least.

Due to loose soil structure, there is a communication of groundwater flow between the water table and the underneath aquifer.

The International Zone shows important infiltration potential on a good portion of its area.

Some canyons and gully have developed through the area where runoff is naturally gathered and drains to the close by Irumbai tank.

Kottakarai village is developed along one of this canyon and seat mainly on the water logged area.

In this context, the area shows an interesting potential for sub surface flow exploitation (western part) which can be enhanced by developing appropriate groundwater recharge devices all over the zone, chiefly through appropriate landscaping.

At the same time the resource is fragile as direct risk of contamination are predominant in such context of shallow aquifer and high infiltration.

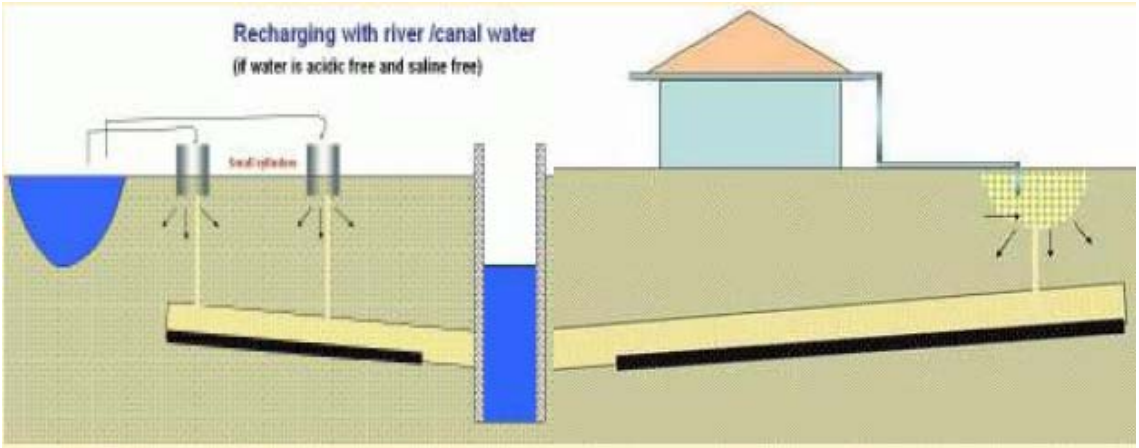
It can be expected that this area and activities can be autonomous in term of water resource by developing appropriate land use, surface water management, pollution control and sub surface extraction devices.

11.2. Recommendations

It is hence recommended to:

- To plan the area in regard to this essential aspect of water resource management as one basic term of reference.
- To work with the natural features, with the slops, with catchment systems and vegetation will create the necessary context for sustainable and appropriate development.
- To integrate buildings, roads and other facilities in such way that it does not arm the water resource but on the contrary enhance the potential.
- To tackle pollution risks, from wastewater generation, solid waste, but also roads and activities as a fully integrated part of the development process of this area but also as a policy for new development.
- To upgrade Kottakarai village as far as water, sanitation and solid waste management are concern, in order to reach necessary safe conditions for the actual population and the planed one.
- To develop a radial well (see picture below) to test the technique and validate the potential for such mode of sub-surface exploitation.

For further understanding of the potential and solutions for integrated water management in this area we suggest to consulate the study *"A Model of Water Resource Management for the International Zone of Auroville"* made by Auroville Water Harvest in July 2004.



Recharging of radials with rain water as well as surface water