INTRODUCTION

TO A GENERAL MANAGEMENT

OF WATER RESOURCES

IN AUROVILLE

2nd DRAFT

A DOCUMENT PRESENTED BY

AUROVILLE WATER SERVICE - HARVEST

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01 May 2002

Years after years, countless information, research, knowledge improvement, development, and implementation have been conducted in Auroville on water related issues. The earliest bare land appealed strongly for special care for water and soil conservation. A substantial part of the collected data and related research are today lost or unknown. Many relevant analyses and reports have to be created at new. This situation, apart of the waste of time and energy it represent, may lead us to very serious mistake in our decisions related to development and implementation: we are today on the verge of a new phase of development, implying vigilant planning and phasing of implementation. Accurate data as much as broad and multi faceted understanding are therefore crucial. It is then time to have in hand a conclusive and up to date view on water situation in Auroville's area.

A. ABSTRACT

Since the very beginning, the water situation in Auroville has followed an in depth evolution on multiple level:

- ☞ From scarcity of resources to the actual abundance, thanks to the improvement and multiplication of pumping structure: Auroville is today dealing with 1 well for 7 people, probably a world wide record!
- ☞ From restriction in the early years to over and miss exploitation today concerning the use: with an Indian standard of personal water consumption of 180 liters per capita per day (lcd) (urban consumption), and a standard consumption in developed country of 250lcd, Auroville is showing an amazing figure of 300lcd!
- ☞ From nearly total run-off to zero percent today in part of greenbelt area: an amazing improvement in surface water and percolation management is the result of years of landscaping and life regeneration.
- ☞ From proximity of good quality ground water to deepening, and salty one: the very sad side effect of green revolution is rushing out.
- ☞ From "one community one (or several) well" situation to the beginning of a cohesive distribution system: the first collective water infrastructure is in use in the residential zone, a second system must be developed soon for neighboring area, and a similar system is under study for the international zone.
- ☞ From totally wild wastewater management to multiple sustainable systems: Auroville is today recognized as one of the most demonstrative place for decentralized wastewater management in Asia.
- ☞ From isolated situation to world wide scientific and technical support: our water situation, understanding and research programs are totally in link with the general concern all over the world.

Similarity, the situation in the surrounding area has completely changed since Auroville's birth. The already severely threaten lands and water are today dreadfully endangered. The main aquifers has dropped of 15 to 20 meters, and an alarming extending salty groundwater his now mapped out in large part of our area, menacing crops but also a major part of drinking water of the villages.

It is time to act.

Today, the very challenging water situation in coastal area is concerning 2.5 billions of people all over the world. It is time to propose a sustainable vision of water management, including a deep vision, deep understanding and reproducibility of the proposed solutions.

B. INTRODUCTION

The strongest evolution of understanding about environmental situation in and around Auroville concerns the awareness at a bioregion level. We can assume today, in opposition to many years of "isolated island" vision of Auroville, than we are fully dependant of the evolution of the surrounding area (on a relatively large scale) for both the quantity and the quality of water. This statement is a valid one on a physical, a practical, as much that a social level.

> The water sources are the same for everybody in the bioregion!
>
> Any valid proposals about general water management of Auroville must include impact study on the surrounding environment, cropping and population.

The time has come to have a comprehensive report on the availability & potential of water in our area and on the scope for future developments by suitable structures for various beneficial purposes.

The present document is therefore giving:

1. A documented analyze of the water situation
2. A strategic approach of the potential evolution in term of harvesting, recharge, consumption, distribution and reuse in all fields of activities related to water
3. A statement of the required steps to reach the needful high level of sustainable water management
4. A definition of the tools, methodologies and studies needed to complete the study and develop an accurate and practical model.

> Whatever have been the idea of general water management of Auroville some years ago, the evolution of the ground reality and our deepening understanding lead to a serious rereading, improvement, and even total revamping of the previously promising solutions.

C. GEOLOGICAL SET-UP & HYDROGEOLOGICAL CONDITION IN AUROVILLE AND ITS BIOREGION

The ground water investigation carried out in the Auroville Township area should envisages to:

- Establish a precise surface and sub-surface geological set-up
- Delineate the aquifer systems worthy of development, their nature, texture and extension both in space and depth
- Establish the interconnectivity with the surrounding area
- Determine the hydraulic characteristics of the delineated aquifers and their behavior during exploitation development
- Project the chemical quality of groundwater and its fitness for utility purposes
- Evaluate and establish groundwater annual recharge and draft relationship.
- Plan suitable groundwater development programme and design suitable structures for domestic and irrigation purposes.

1. INTRODUCTION

Groundwater 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, groundwater 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 require no mentioning, causing adverse effects on the hydrologic balance and quality of water.

The studies carried out by Harvest in some of the villages in the Kaluvelly watershed showed excessive extraction of ground water in the region and seawater intrusion in some of the coastal villages. High salinity 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, and therefore Auroville.

The consequences of such intrusion would be disastrous, as it will affect the irrigation, which is largely dependent on groundwater. Water for drinking purposes will also become scarce in the villages and township like Tindivanam would see its main source of drinking water badly affected. It is also identified that the ground water in some of the villages in the Vanur region contain Fluoride beyond the permissible limits of WHO's drinking water standards.

A suitable appreciation of the geological and hydro-geological setup, as well as the groundwater evolution these last years, will confirm the relevance of global water management scenarios proposed.

2. LOCATION AND EXTENT

Auroville Township is located about 8 Km North West of Pondicherry and has presently an area extent of around 1200 H.A, spread over an area of 42 Sq. Km, and is close to the sea coast. In the north, Auroville is bounded by the Kaluvelly Tank, in the South by the Union Territory 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.

3. PHYSIOGRAPHY

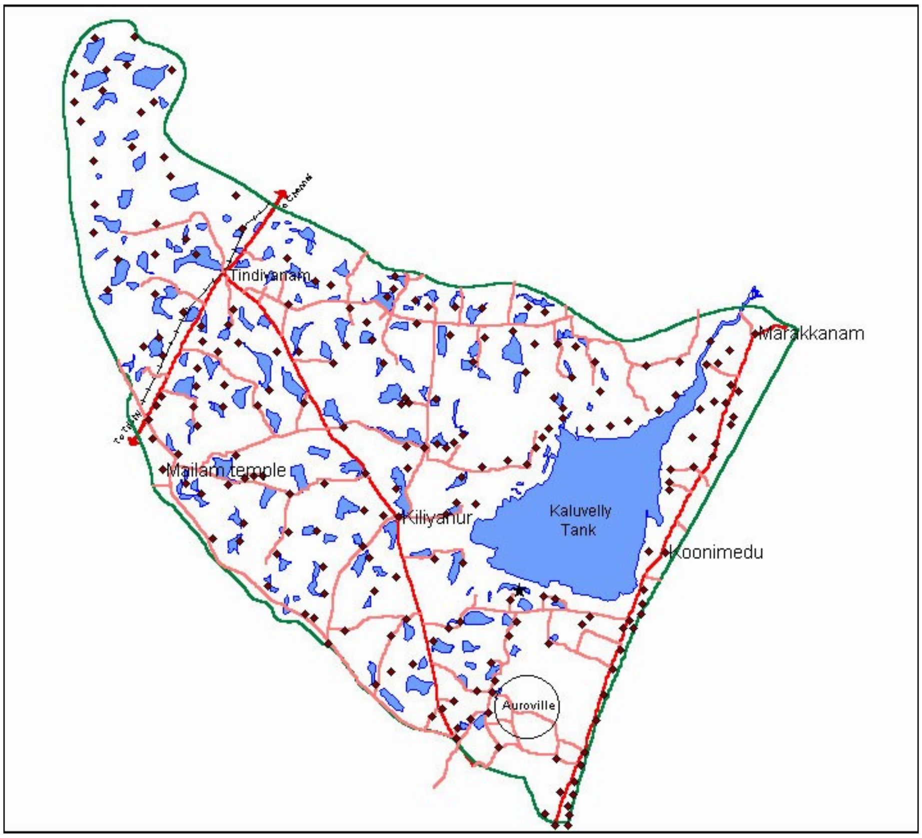
The center of Auroville Township is located on a high ground at an altitude of about 52m above mean sea level (MSL) recording steep and gentle slopes in the west, gradients being 0.6 and 1.1 percent respectively. The high grounds run in the NNE – SSW Direction being parallel feature to the topo 'Low' in the western part.

Along the high ground, short flow courses of well-formed gullies and drainage towards west (topo-low) are observed. Similarly a few streamlets do occur in the eastern slopes of the Auroville drainage towards the sea.

The shallow Kaluvelly swamp located to the North of Auroville has an area extent of 60 Sq. Km and forms the main outlet for the gullies draining in the Northern and Western parts of the Auroville area.

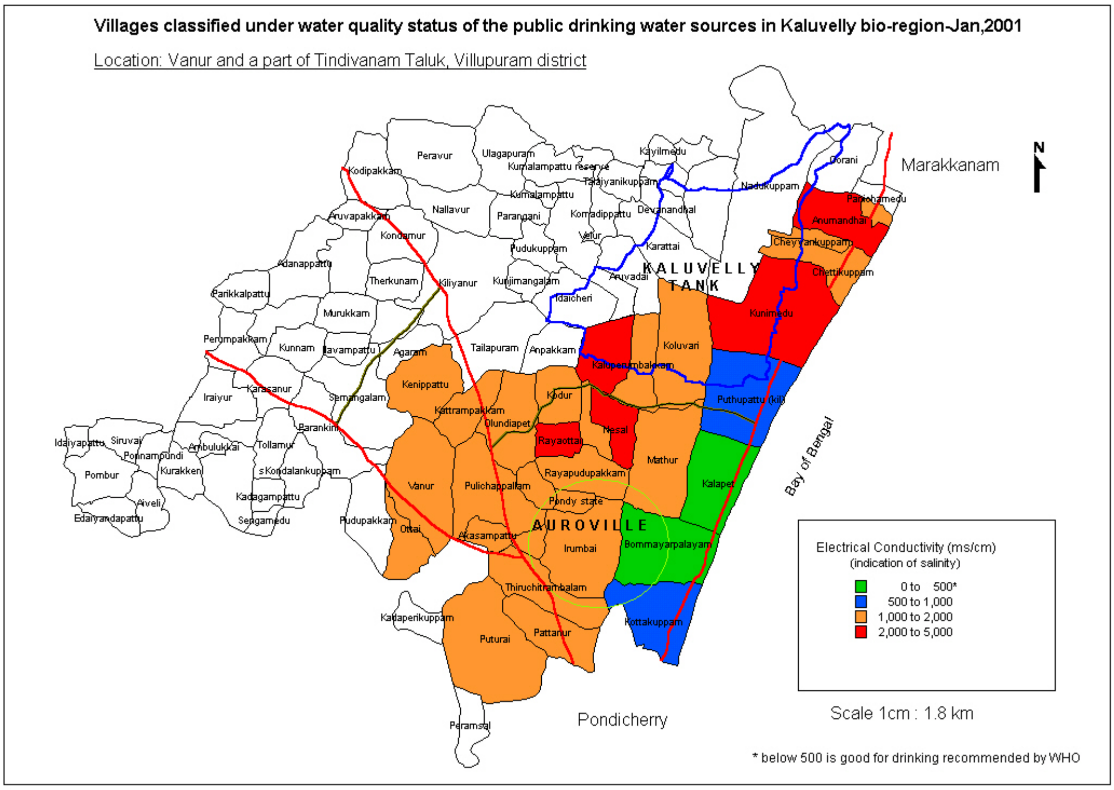
At a larger scale, Kaluvelly swamp is the natural outlet for a large area extent of around 750 km2, constituting by itself a watershed. The so-called Kaluvelly watershed includes multitude of gullies and canyons, 196 major tanks and 220 villages with consequent population and related activities. Together, it is considered as the Auroville bioregion, even if other parameters (i.e. groundwater) can enlarge it to 2000 km2. Sub-watershed can be identified too within this watershed, with local specificity. There is no perennial river system in the bioregion.

Because of its geographical specificity, natural integrity and clear frontiers, the Kaluvelly area is commonly identified as the Auroville bioregion. We can assume to a certain extend that the entire water evolution of our area will be integrated in the bioregion development. Therefore, our approach of water management of Auroville must be fully in scope with this larger area.



Kaluvelli Watershed or Bioregion

Salty water is strongly emphasized here and there and increases very quickly with a consecutive wider impact. The main reason is the quick depletion of water tables because of mismanagement of the water bodies and drainage structures all over the watershed (and all over Tamil Nadu either) and tough over-pumping for irrigation purpose mainly.



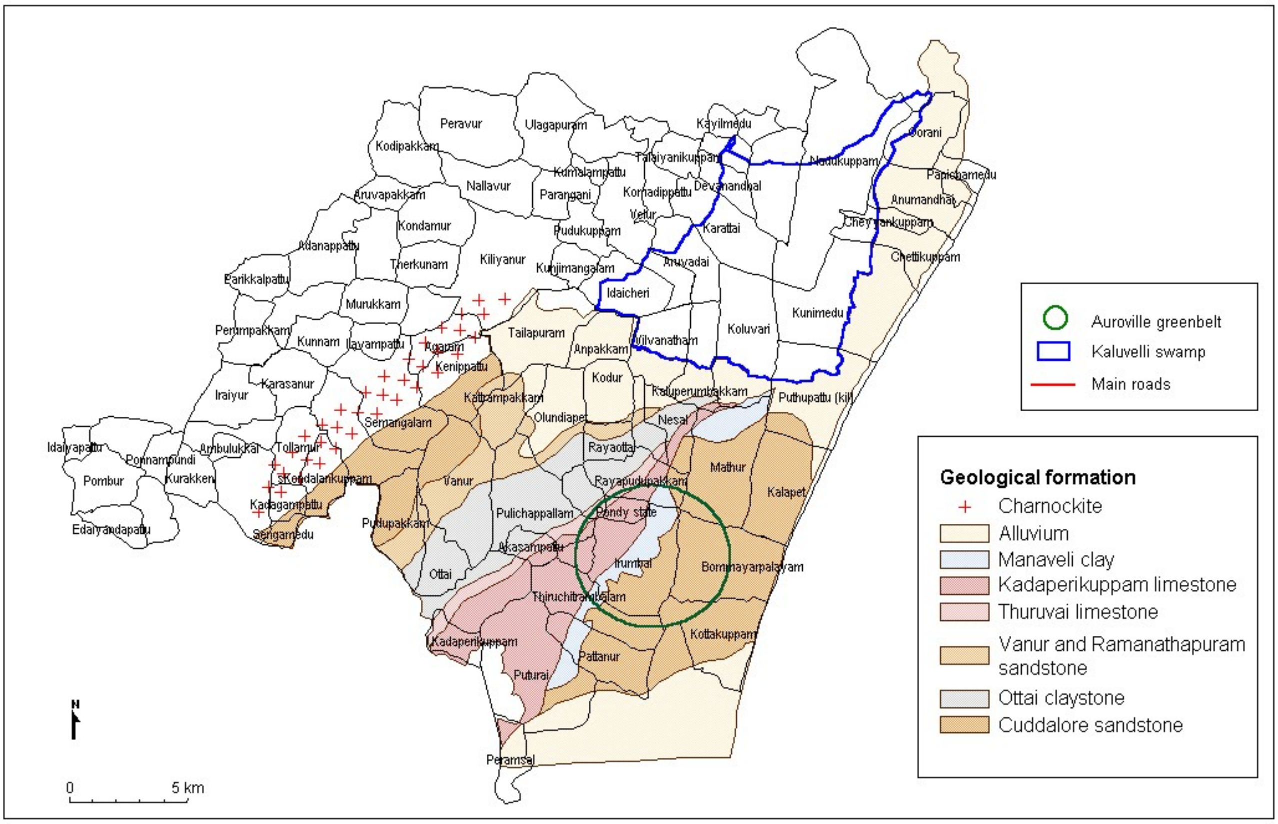
<u>Drinking water quality status in Kaluvelly bio-region</u>

4. GEOLOGY

In the major part of Auroville area sedimentary formation, laterite and sandstones of Pleistocene and Miopliocene periods are exposed. Sedimentary formations (clay and limestone) of Pleistocene period are exposed in the Western most part of this area. Based on the study of aerial photos on 1:20,000 scale and selected field cheeks Mio-pliocene and Paleocene formations is demarcated.

Exploration by ONGC (Oil and Natural gas Commission) and CGWB (Central Ground Water Board) in the region has brought to light the presence of sedimentary formations (Clay stones, lime stones and sand stones) of cretaceous age and the crystalline rocks (Charnokite) Achaean age at depth below the Miopliocene formations.

GEOLOGICAL FORMATIONS OF THE PROJECT AREA



The Kaluvelli watershed, 730 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 granitic composition (K feldspar, Quarts, plagioclase, hypersthene 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 of the watershed, 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 lateritic 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).

Stratigrahic successions:

Era	Period	Formation	Lithology
Quaternary	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 fossiliferrous limestone, calcareous sandstone and clay. --------------------------
Mesozoic	Upper Cretaceous	Thuruvai limestone	Highly fossiliferrous 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, silty clays and fine to medium grained sands with bands of lignite and sandstone, medium to coarse grained. ----------------------------
Archaeans		Eastern ghat complex	Charnokite and biotite Hornblende gneisses.

As per the geological report of CGWB (1984) about Vanur region, the Archean crystalline rocks comprise of Charnockite and Biotite-hornblende gneiss's and form the basement to the thick pile of Mesozoic and Tertiary sediments.

During the drilling made by the farmers and DANIDA (1999) for drinking water bore well in the villages of the project area, lithologies on different depth were collected. Accordingly depth of each formation was confirmed and thickness of each formation of the area is given below.

The Cretaceous sediments comprise three distinct formations in the project area: Ramanathapuram sandstone, Vanur sandstone and Ottai claystone.

Ottai claystone outcrop in the southeast portion of the project area and the thickness is ranging from 10 – 12m.

Vanur sandstone is exposed on a larger area of the central and northern part of the project area and the thickness is more than 150m in the villages of Kattrampakkam and Vanur, found during drilling of bore wells made by the local farmers.

Cuddalore sandstone is outcropped over the west and northwestern portion of the project area covering the villages of Kenipattu and Vinayagapuram. The thickness is encountered approximately 68m in Kenipattu and 113m in Vinayagapuram at the time of drilling made by DANIDA for drinking water bore well.

5. HYDROGEOLOGY

In Auroville and its Bioregion, the groundwater occurs in the intergranular pore space of the sandstone. As stated earlier, it is chiefly occupied by the sedimentary formations underline by the crystalline basement.

Four main aquifers are exploited from the ground:

1.Charnokite aquifer

2. Vanur sandstone aquifer
3. Cuddalore sandstone aquifer
4. Alluvium aquifer and sands of the coastal dune.

Groundwater occurs in the both Semi-confined and confined condition of the aquifers.

The Vanur sandstone of cretaceous period and Cuddalore sandstone of Tertiary Era constitutes the potentials aquifers in the project area.

a) The discontinuous aquifer of charnokites

It presents a high salinity (3200 μS/cm), and is therefore usually little exploited.

b) Ramanathapuram aquifer

Not used because of sulphide content,

c) Vanur sandstone aquifer

The bottom aquifer, Vanur sandstone, is the least altered of the area aquifers. However, Vanur sandstone water electrical conductivity increased for some years and its water table decrease drastically. Because most of the wells are not cased, waters pumped from deep wells can be a mixing of top aquifers + Vanur sandstone, and so the resulting conductivity.

The thickness of the productive zone varies from 12-72m. The depth of occurrence of granular zone is around 12 – 80m and the piezometric surface vary from place to place from 23 – 35m based on mean sea level (msl), as per the study made by DANIDA and TWAD. Tube wells of the area are tapping the sandstone aquifers under confined condition with an average well depth of 95m (based on ground level).

The average discharge from the tube wells was found as 10 – 12 l/s (36,000 – 43,200 l/h). Pumping test done by DANIDA (1999) in the villages such as Vanur and Kenipattu reveals that the Transmissivity rate of the Vanur sandstone is 156m²/day and the rate in Cuddalore sandstone is 77m²/day.

Unconfined at the vanur sandstone outcrop, it becomes ottai clays.

Because of good hydrodynamic properties (transmissivity between 800m2 and 250m2, 1948), this aquifer was a reservoir of high quality and adequate quantity for several years. 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.

Natural flow goes from NW to SE with a hydraulic gradient from 7 to 35.7m in the study was done in 1948. Waters of the Vanur sandstone aquifer show varying electrical conductivity from 950 µS/cm to 1750 µS/cm related to space and related to time depending on climatic conditions and pumping rate.

This aquifer could be in hydraulic connection with:

- Seawater of the Bay of Bengal;
- Saltwater waters of the Kaluvelly swamps (2700 to 21000 µS/cm)

d) The cuddalore sandstone aquifer

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 following 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.

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.

Natural flow goes from NW to SE with a hydraulic gradient from 7 to 28.5m (1948). Transmissivity and field permeability of the aquifer ranges from 420 to 600 m^2/day respectively. As cannot seen in the western portion. 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.

e) Kataperikuppam formation

is essentially calcareous sandstone, yellowish to dirty white in co lour. It also comprises thin lenses of clay and shale and bands of shell limestone. No data about thickness is available at outcrop area. At kallapettai, along the coast thickness of the formation is about 180m but towards outcrop the thickness is gradually reduced to 31m at Lake estate. Higher thickness at madhagadipattu (185m) and Madhukkarai (128m) are noted where as it is reduced again at sattamangalam (107m). This variation in thickness may be, because of irregularity in the cretaceous basement.

Transmissivity and field permeability of the aquifer ranges from 320 to 460 m^2/day. Water electrical conductivity range between 785 to 975 microsimens / centimeters near the Kaluvelli swamps.

f) Ottai clay stone formation

is outcropping relatively in larger area than other cretaceous sediments; covering the villages Ottai, Pullichapallam and Rawthankuppam. It is mainly black to greenish gray clay stone with a few bands of calcareous and micaceous siltstone. Thickness of this formation is about 139m at karasur (Just close to outcrop) and greater than 231m at Lake estate though it is only 88m at kallapettai. Thinning of the formation at Auroville and further at kallapettai 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

g) The aquifers of alluvium and sands

are unconfined but shows high electrical conductivity because of their proximity to seawater of the Bay of Bengal and saltwater of the Kaluvelly swamps.

h) Tertiary formation of sandstone

In Auroville area, tertiary formation of sandstone that is unconformable with the other sedimentary beds. They have been eroded or they have not deposit 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 and 875 μS/cm near the Kaluvelly swamps. Its potential reserves are limited.

6. DEPTH TO WATER LEVEL

Presently, there are 121 observation wells (Abandoned wells) in the project 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 hydrographic has been prepared with water level and rainfall for each well. The maximum water level of 67m bgl (52m below mean sea level) was observed in Kattrampakkam during the year 1996 because of the monsoon failure in 1995 (45% deficit). After that water level came up to 35m bgl during June 1998 as a consequence of consecutive heavy rainfall in 1996 & 1997. Then it further came up to 22m bgl during January 1999 due to excess rainfall in 2001. The seasonal change in the water level varies from 4m to 14m.

The water level of Vanur during April 1999 was 27.35m bmsl and is showing a declining trend to 36-m bmsl during September 2001. During the last 6 months period water table has fallen down 9m. It shows the extraction rate of groundwater is manifold of annual average recharge by rain.

i) HYDROCHEMISTRY

Though the neighboring villages (Rayaottai and Vilvanatham) are affected by seawater intrusion, the groundwater of the project area has not yet been affected. Still it is under safer position; however, over extraction of groundwater might bring the seawater intrusion in the near future. The area is 14 km from the seaside.

The electrical conductivity (as an indicator of Salinity) of the groundwater of Vanur and Kattrampakkam show 530 micro-siemens (μS/cm), and 980 μS/cm respectively according to the recent monitoring data (September 1999) on groundwater quality. But the quality of the groundwater of Rayaottai and

Vilvanatham (neighboring villages) are poorer than the project area as they have high electrical conductivity of more than 4500 µS/cm.

As far as the quality of the drinking water is concerned, groundwater of the project area is fit, as it possesses the level of minerals inferior to the WHO standards. Meantime the groundwater of Rayaottai (6 km from the area) is highly unfit for drinking purpose, containing high minerals, showing the electrical conductivity level of 8000 µS/cm (December 1998).

For agriculture, the groundwater of the project area is fit because of tolerable levels of sodium. The sodium content in the groundwater of Vanur and Kattrampakkam is 30 and 40 mg/l respectively. But in Vilvanatham, the groundwater contains high amount of sodium and chlorides, affecting agriculture adversely.

Our recent quality monitoring data reports are given below in the table.

S.No	Name of the Aquifer	Electrical conductivity (Micro siemens / centimeter)
1	Cuddalore sandstone	385 to 875
2	Kataperikuppam sandstone	785 to 975
3	Vanur sandstone	2700 to 4500
4	Ottaiclaystone	750 to 1250
5	Manaveli clay	780 to 920
6	Charnokite	3200

j) INTERCONECTION BETWEEN AQUIFERS:

Interconnections between different aquifers play 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 Ottai claystone formations, and also installed at varies locations of water level data from piezometers installed at the same site but in different aquifer e.g. Cuddalore sandstone and Vanur sandstone formations. These studies are further supplemented and supported by the hydrochemistry and environmental tritium studies.

k) GROUNDWATER RECHARGE STUDIES:

Evaluation of groundwater is vital for the management of groundwater resources. The rate at which water can be withdrawn perennially under specified operating conditions without producing undesired results is called safe yield. This principally depends upon the natural as well as artificial recharge sources.

There are several methods to evaluate natural recharge, which include conventional and tracer methods. Conventional methods employ the empirical relations to estimate runoff from rainfall data and evapotranspiration from the climatic factors making use of various formations available in the literature and recharge is estimated as a difference between rainfall and sum of runoff and evapotranspiration.

Tracer techniques make use of artificial as well as environmental tracer. For the present work, recharge has been estimated using the environmental chloride and injected tracer techniques. With in the framework of the environmental chloride method two approaches have been used viz., concentration method and flux method. Using the injected tritium method the recharge has been estimated at about 6 sites and later comparison between the results of the two methodologies used is studied.

l) GROUNDWATER MOVEMENTS AND AQUIFER PARAMETERS:

Groundwater movement is generally studied conventionally by the data of hydraulic gradients and aquifer parameters estimated using the 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/d1 is hydraulic gradient.

In the present investigation environmental tracers, tritium and radiocarbon (carbon-14) are used for deciphering groundwater movement.

The principle generally used for such purpose is to estimate the age of transit time of groundwater. Transit time (age) of groundwater is defined as the time elapsed since meteoric water entered the aquifer system. Thus, in principle, age of groundwater can be found by measuring the concentration of radioactive nuclides (such as tritium, carbon-14, Silicon-32 etc.) That occurs naturally in ground water and comparing its concentration with the original or initial activity when the water was recharged, assuming that there is no source or sink of radioactivity and loss of radioactive decay.

Tritium isotope (half-life 12.43 years) study is more suitable for waters, which have short turnover time. Radiocarbon is useful for the study of deeper groundwater where transit time is expected to be large. Though there are problems in the determination of absolute carbon-14 ages, the method nevertheless provides a convenient technique to study the movement of groundwater and to estimate ground water velocities.

Two French scientists (Camp University), Nathalie GASSAMA, Lecturer, Water chemistry and Sophie VIOLETTE, Lecturer, Hydrogeology, are studying the Kaluvelly watershed area for monitoring the quality as well as water level, which is to find out the seawater intrusions.

The main aim of the study is

- To understand hydrological and geo-chemical components of the coastal Kaluvelli catchment's area by deploying a multidisciplinary approach.
- To determine the origin of salt in waters of Vanur sandstone, with quantification and characterizations of the 5 sub-unit mixing system (charnokite aquifer, Ramanathapuram sandstone aquifers, waters of the Kaluvelli swamps, Ery waters and rain waters.
- To quantify the hydrological balance of the multi-layered aquifer with a coupled underground and subsurface flow model constrained by geochemical tracers.

This study imply the participation of heavily equipped laboratory in France, geo-chemical tracers being isotopes elements. We may expect some result on this study in the coming months.

7. HYDROLOGY – OCCURRENCES OF GROUND WATER

In Auroville area, groundwater generally occurs in the inter-granular pore spaces of the sand stones. It also occurs in the fractures of the hard and compact limestone. In the area Groundwater takes place both under unconfined and confined.

As stated earlier, Auroville area is chiefly occupied by the sedimentary formations underlain by the crystalline basement.

Where is the Water of Auroville?

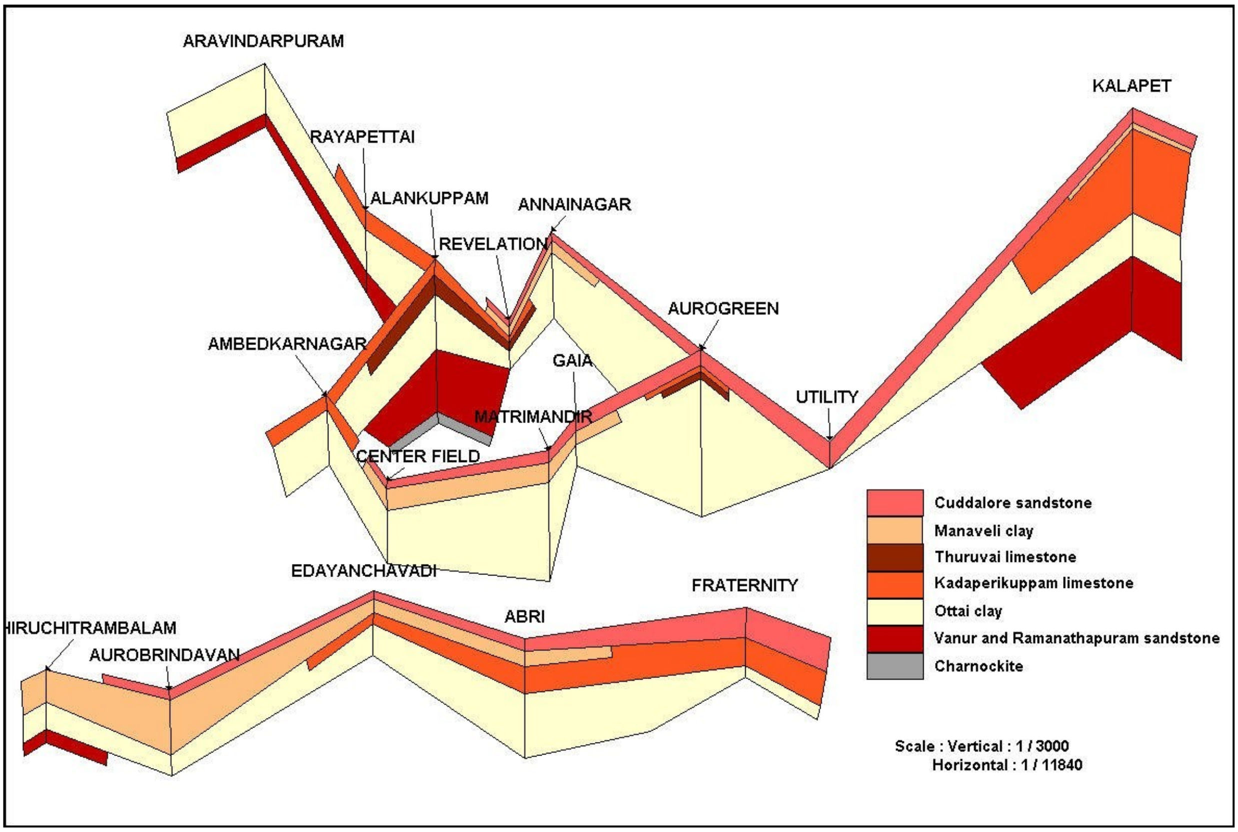
The sand stone of the Cuddalore formation (tertiary), sand stones and lime stones of the Kataperikuppam, Vanur and Ramanathapuram (Cretaceous) formations constitute the potential aquifers in the area, though some granular zones exist in the Manaveli and Ottai formations (cretaceous) they may not form promising aquifers due to their limited area extent and poor permeability but may yield meager quantities of water due to leakage from other aquifers. Hence the Manaveli and Ottai formations act mainly as acquitters.

The ground observation demonstrates that there is a very important fluctuation of water availability within Auroville, even between to adjacent wells. The principal cause is due to the very complex structure of the ground, which may fluctuate from a single massif bed of very favorable material (as 100 meters thick sand stone), to a very thin stratification of intercalate materials, each one with its one water potential. Practically, the variation can be as large that 1cum/hour to 10 cum/hours of groundwater yielding potential within a 10 meters distance (well to well). This must be understood to get the difficulty to assess the groundwater availability.

8. FENCE DIAGRAM

The sub-surface geological configuration of Auroville areas is well brought out by the Fence Diagram prepared based on the data obtained during ground water exploration of the CGWB and during the exploration for oil and Natural Gas commission (ONGC).

The extension of crystalline basement from west to east and the thickening of the formation generally towards east and southeast are brought out sharply in the diagram.



D. OUR GROUND WATER SITUATION

Ours “own” aquifers present some very weak point.

- The first one, close to the surface, is nearly exhausted today, (apart of north-west area of the plateau which is vertically limited by a thick layer of clay, avoiding vertical leakage but recharge). The recharge from the top is much better that during Auroville early years, thanks to afforestation and soil regeneration. We can therefore presume that the depletion is coming from two factors: vertical leakage to the second aquifer through shortcuts created by the wells. As it is relatively close to the surface, this is probably the main water resource during dry period for the plants, both directly (deep root plants) and per soil capillarity.

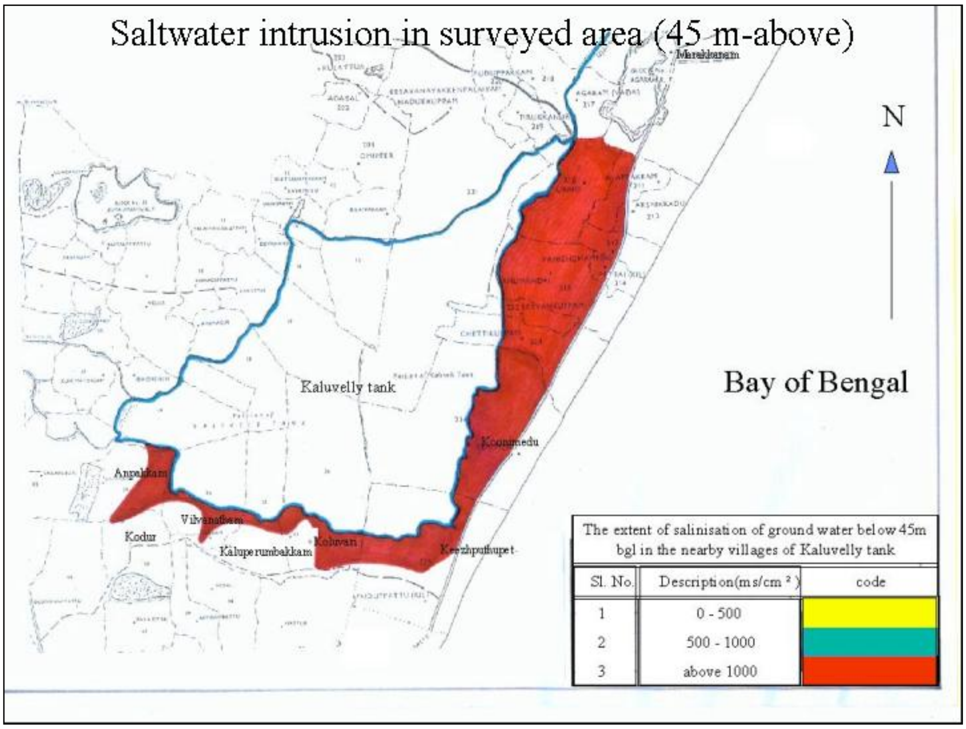
  The water is of very good quality and presents generally a very good taste. This aquifer is fragile as far pollution is concern because of the surface proximity and possible shortcut to the outside (termites, roots, cracks). Apart of eventual organic pollution, the main risk comes from chemical impact: accumulation of hydrocarbures and pesticides. Pesticides are well known for cumulative effect and slow bio-degradation. The ones specially used in the area have a very long lifetime and a long migration process trough the ground. Even by stopping immediately spraying (and over-spraying) dangerous pesticide on the all Auroville plateau, the bad side effect on groundwater could be acting for decades (DDT).

- The second aquifer (Cuddalore sand stone) is today our principal extraction source. There is however vertical leakage to the 3rd one for the same reason than the first one. The quality is a bit less, but the pollution risk is less too, providing sufficient protection from the wellheads, main pollution door. This too underline the very needed urbanization planning to protect our water. The main advantage of this aquifer is that it is tapped mainly by Auroville (in our area), therefore much more easy to control and not directly under seawater intrusion pressure. The quantity of water available from this second aquifer is anyhow limited, and will require a strong program to protect it from over and bad exploitation, and from bad technical practice.

- The third aquifer (Vanur sand stone) is very important, mostly shared with the neighborhood on a large scale, very much over-pumped and directly under salinity impact. In certain area, it is however very well supplied and from a very good quality. The main difficulty is that the movement of the water in the soil is not homogeneous, allowing very different hydro geological scenario, and subsequent quality variation. A program is going on with French scientists to understand the general process.
- The deepest aquifers are not relevant for normal used. They are not drinkable and not suitable for irrigation purpose either. Our main concern about these deeper waters is to avoid or to stop any vertical lost from the above ones.

The heavily depleted aquifers and subsequent quick salinity inflation process is already badly visible in our area, and mainly around Kaluvelly swamp, our main water storage system. Kaluvelly swamp is the natural exhaust point of the bioregion and a very fragile ecosystem because of its particular location close to seashore. This emerges as no availability of drinkable water, lost in crop intensity, mineralization of the lands, and finally migration of the population for more hospicious places.

High salinity is already appearing locally in Auroville itself: it is not a foreseen difficulty but a factual reality.



Our main emphasis today is to understand the situation, and particularly the preoccupation coming from the seawater intrusion. Several programs conducted by Auroville Water Service-Harvest are going on in the bioregion to reduce this intrusion and fight against general degradation of our common water resources with multiple activities program. Because of the acknowledged particularity of Auroville's integral approach and the already very promising results of previous and ongoing projects, support from central government, local government and institutions, as well as international organizations are coming and growing very fast.

> The origins of fast salt concentration in our aquifers are well known: over-irrigation and lack of general management of the water resources. Therefore, our emphasis must be to develop a model structure in Auroville, both for municipal purpose and for agricultural purpose.
>
> To reduce the use of water, to develop low water input agriculture, to favorite high water reuse, to reduce lost of water with sustainable drilling methods and to control evaporation by developing organic

farming, including rotation techniques, to develop free pollutant agents agricultural and industrial practices…

A multi disciplinary approach is required and should imply major part of Auroville's strength.

This is, anyhow, our main physical challenge for the coming years in Auroville as much than for the neighborhood, and then must be anticipated as our most demanding effort of consciousness at this level.

m) The actual devices of Auroville study the ground water situation include:

- A database of around 1200 wells located in and around Auroville, 220 wells in Auroville itself.
- 120 wells very regularly checked, both within and around Auroville as indicator of piezometry (height of water) and salinity control.
- Above 100 wells with data on their Lithology.
- Lab facilities (with EMS), allowing a large environment follow-up, especially in the field of pollution control.
- A top level Geographic Positioning System (GPS) allowing locating very precisely any water devices.
- A Geographical Information System (GIS), AWS hosting actually the research platform for this activity in Auroville.
- An Automatic Weather Station fully equipped and computerized.
- Partnership with top world level laboratory dedicated to water investigation (isotopic study, chemistry).
- Access to CGWB's resistivity system and result. This allows collecting geological data in a soft way without going for blasting method and with great accuracy.

E. RESOURCES FROM THE RAIN

1. GENERAL STATEMENT

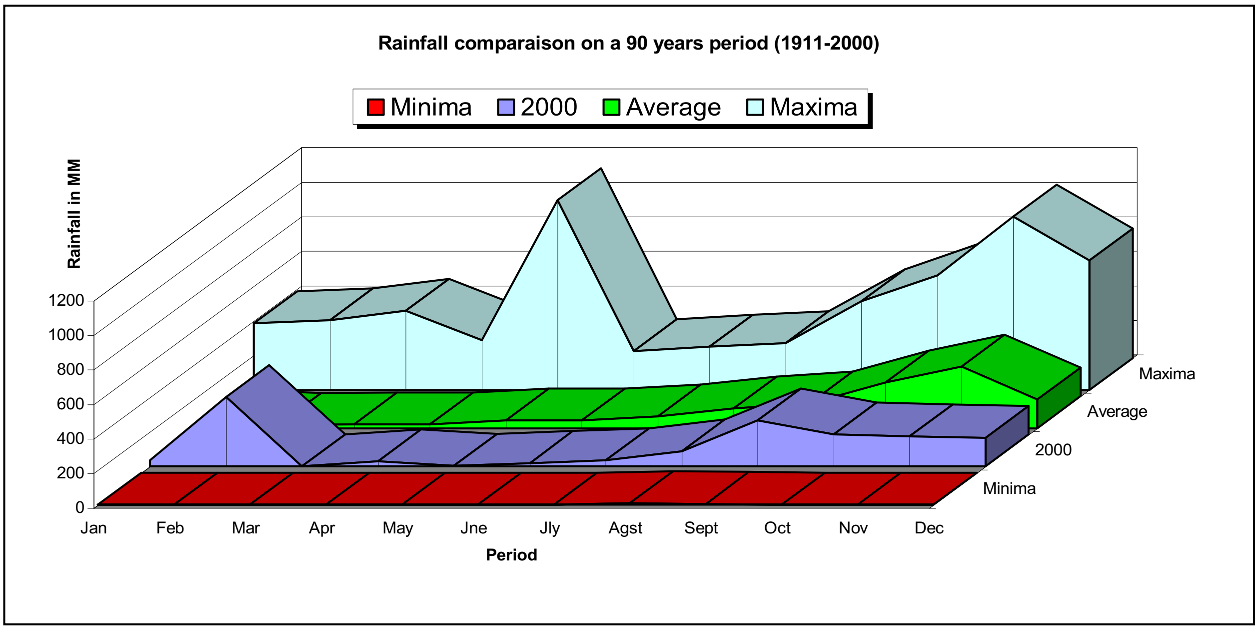
Ultimately, the entire water resource for Auroville area comes from the rain: there are no perennial rivers, and the ground water availability rise and fall very much according to rainfall pattern. It is therefore understood that a rigorous analyses of rainfall pattern, climate and microclimate variation follow-up are essentials to assert relevant water management plan and implementation program.

The following table gives an estimated yearly water resources from rainwater, starting from an average rainfall of 1,293 mm per year (calculated on a 90 years period).

	Surface sqm	Equivalent received rain cum	Estimated Lost by evapotranspiration cum
City area	4,908,739	6,342,090	4,841,380
City area with green belt	19,634,954	25,368,361	19,365,519

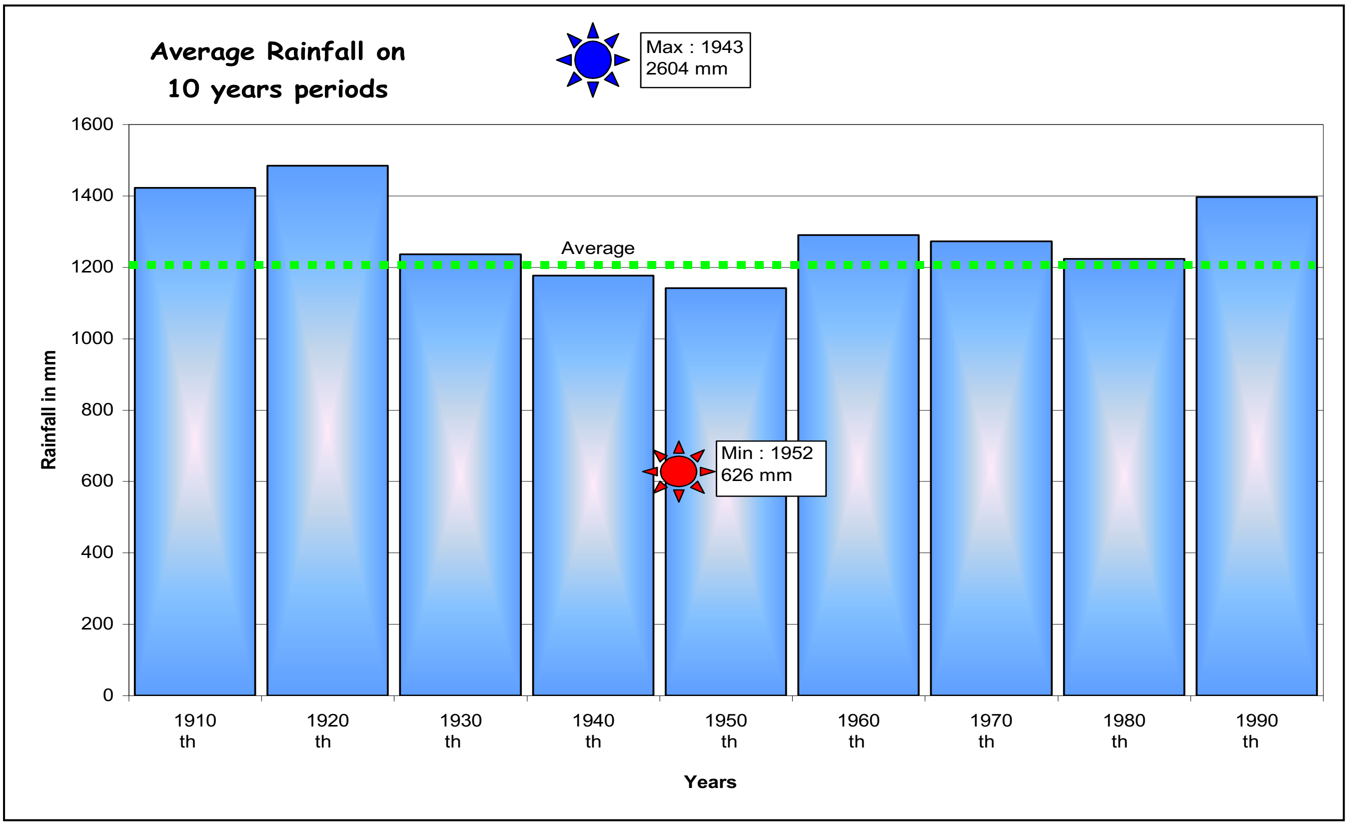
Because of the washing and erosion effects of the rain, the actual programs of erosion control going on in Auroville (field banding, check dams, organic stabilization), which has proven to be very efficient, must be developed, improved and extended to the surrounding area. A very important recharge effect is generated by this way, as the zero runoff observed in certain area of Auroville proves. No runoff means groundwater recharge.

Crucial information about the rainwater resources concerns the repartition of precipitations all around the year. Even if the inter-tropical area is generally recognized for the regularity of its rain scenario, the observation proves that there is a lot of fluctuation, with very important side effect on the field cropping pattern, and human life quality: flood, drought… The control runoff structures and percolating devices have therefore to be designed accordingly.



It is equally observed that for a comparable rainfall quantity, the intensity plays a major role on the water table recharge. A time sprayed rainfall will have much better impact on the shallow water table than a concentrated one. On the opposite, it seems that the impact on deep aquifers is better with concentrated rainfall, and less on shallow ones. For example the year 2001-2002 shows rather good water availability on open wells in the International zone and adjacent green belt area, whatever the relatively poor rainfall. On the opposite, the Industrial zone has been little affected by this rainfall pattern, conducting to a fast depletion of the open wells in this area. This confirms the lithology.

An even more crucial element is the fluctuating quantity. By looking on a large timescale, we can easily emphasis the very important fluctuation of rain quantity reaching Auroville area, with minima cum maxima comparison showing an amazing fluctuation from 1 to 4 times the amount of yearly rainfall!



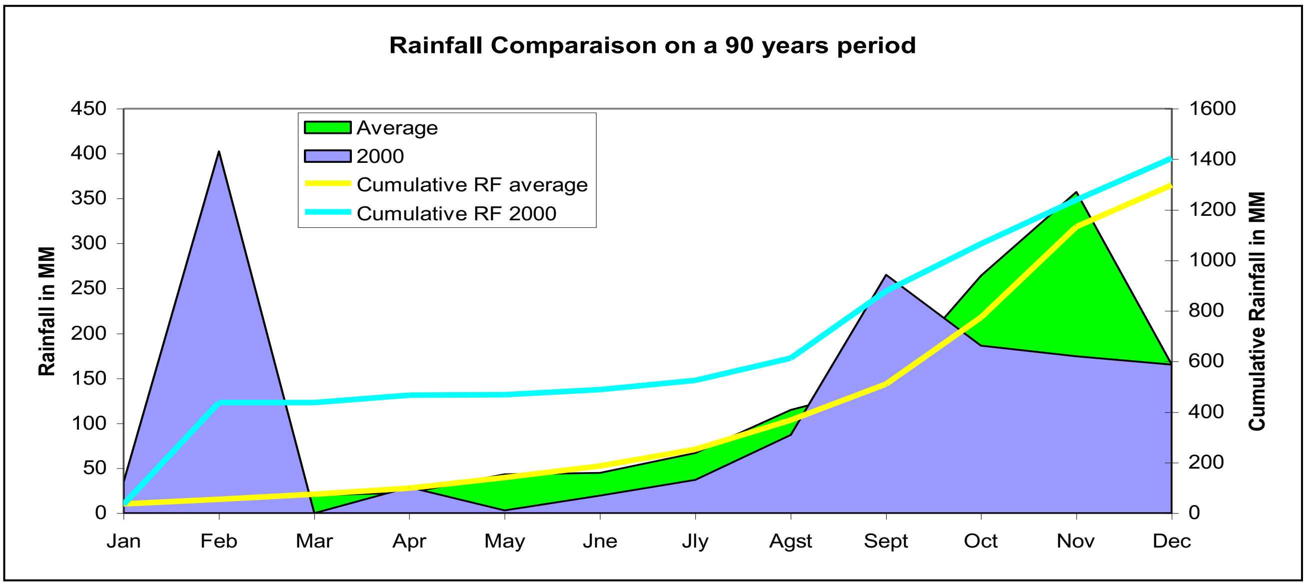
The consecutive impact on the aquifers and therefore groundwater availability must be foreseen on a rather large timescale period.

If the average rainfall is 1293mm on a 90 years period (data coming mainly from Pondicherry weather station) 1943 is known for an amazing 2604mm yearly rainfall (in Pondicherry), mainly because of a cyclone during May of this year (maybe the one mentioned by Mother when Sri Aurobindo's room was absolutely not disturbed in spite of the storm), and 1952 was a very dry year with 626mm rainfall.

Exceptional event?

By looking to the repartition of rainfall per year, the analyses show: 61% are below average, 39% above. 18% of the considered time period is showing rainfalls shortage equal or below 75% of the average (970mm). 23% is showing rainfalls excess above 125% of the average (1610mm). We can consequently assume that nearly half of the yearly rainfalls are showing heavy fluctuation (± 25%) if to compare to average. Water management of Auroville must been then foreseen accordingly

On top of these multiple fluctuating factors scenario, a worldwide alarm is newly coming and seems to been confirmed by last analyses: global warming.



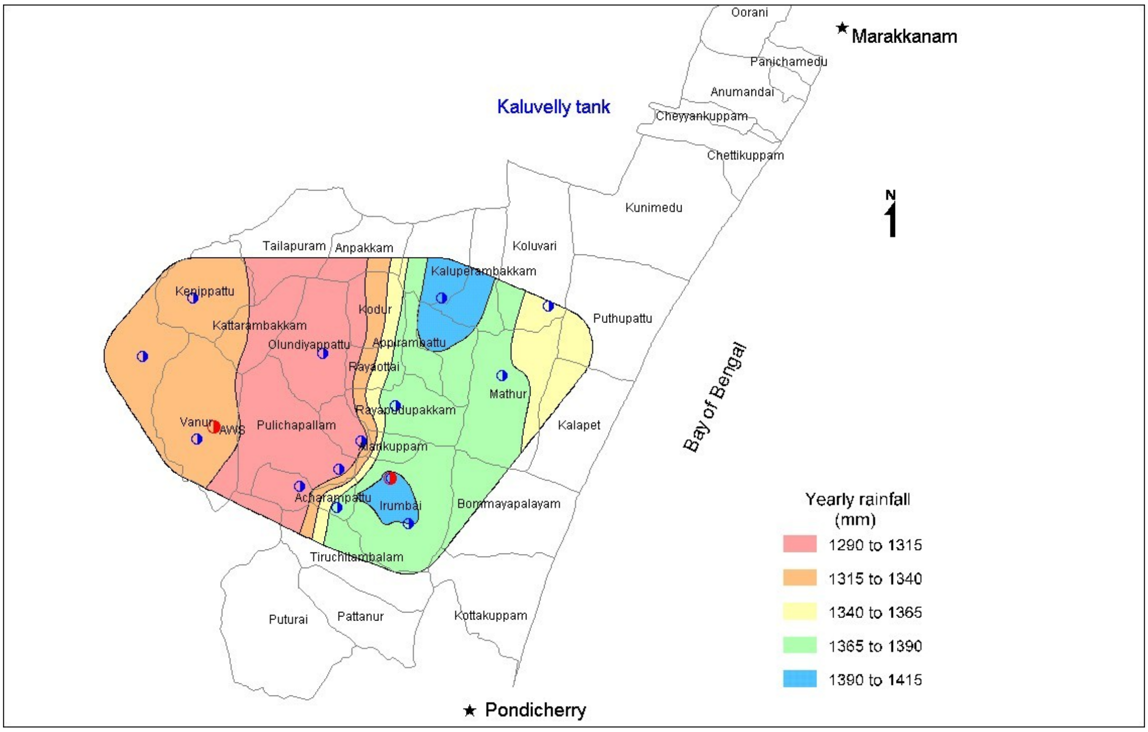
It is for the time being very difficult to foreseen what can be the effect of such event in our area, because the weather situation in tropical belt is considered as very stable and slow to react. There are controversies within Indian specialist obout potential effect on this area, some considering only temperate latitude as being concerned by such alterations. However, the lasts year rainfalls fluctuations seem to be part of the global warming scenario, but no obvious fact can prove it today.

Auroville (through AWS) owned a complete automatic weather station, which will allows conducting in depth analyses of weather evolution and, together with simplified weather survey at a village level, to study microclimate variation. The latest is one of AWS-Harvest programs, and is designed as an awareness device to water cycle, water recharge and understanding of local evolution.

2. LOCAL WEATHER SCENARIO

Why rainfall varies from place to place. Of course it is a matter of condensation and direction of Wind flow. At larger level the Coastal, Forest and Hilly places get proportionally more rain than the other places. That is what can be observed on the map below. The difference is not a matter to the public; it only matters to Researchers and Developers and it may also affect to a certain extend cropping pattern and intensity. The micro level climate studies can give the error free derivation from theoretical calculations like runoff, infiltration and other water related studies.

A micro level weather studies has been conducted in the Auroville bioregion. We distributed 14 rain gauges and thermometers to the village volunteers who are participating in Harvest's Hydrological extension study using participatory methodology. The Tamil Nadu Council for Science and Technology sponsored the study. Appropriate training was provided to the volunteers to record the rainfall data and temperature. The data collected from these volunteers helps us to generate maps, which indicate the exact rainfall scenario of the region.



The Region map below developed from the Annual rainfall of 2000 (Recorded in each station from 1st of January to 31st Dec, 2000 at 6.00 am)

F. RUNOFF AND INFILTRATION: THE ENCOURAGING PART

The rainfall scenario has a direct impact on the runoff and groundwater recharge. If the intensity is excessive, the soil does not have the capacity to infiltrate it. Above a certain intensity cum quantity, the control runoff structure are over passed with consecutive risks of overflowing the storage structures, normally sized by taking in account a infiltration ratio, which is on its side linked to soil coverage and land shape. This factor is even worst if the soil does not have been preliminarily wetted. In term of rain efficiency on the soil (important infiltration rate) regular and well-sprayed rainfall is the best.

For example, winter monsoon scenario 2000 had a very low impact on water table recharge, despite the good amount of rainfall on the full year period and the relatively good monsoon rainfall (85% of the average for this period). We can even speak of a monsoon failure, if to compare to environmental impact: tanks does not have been recharged and were nearly dry beginning of march already, which does not allow normal post monsoon cropping.

Our main objective concerning Rainfall impact must be:

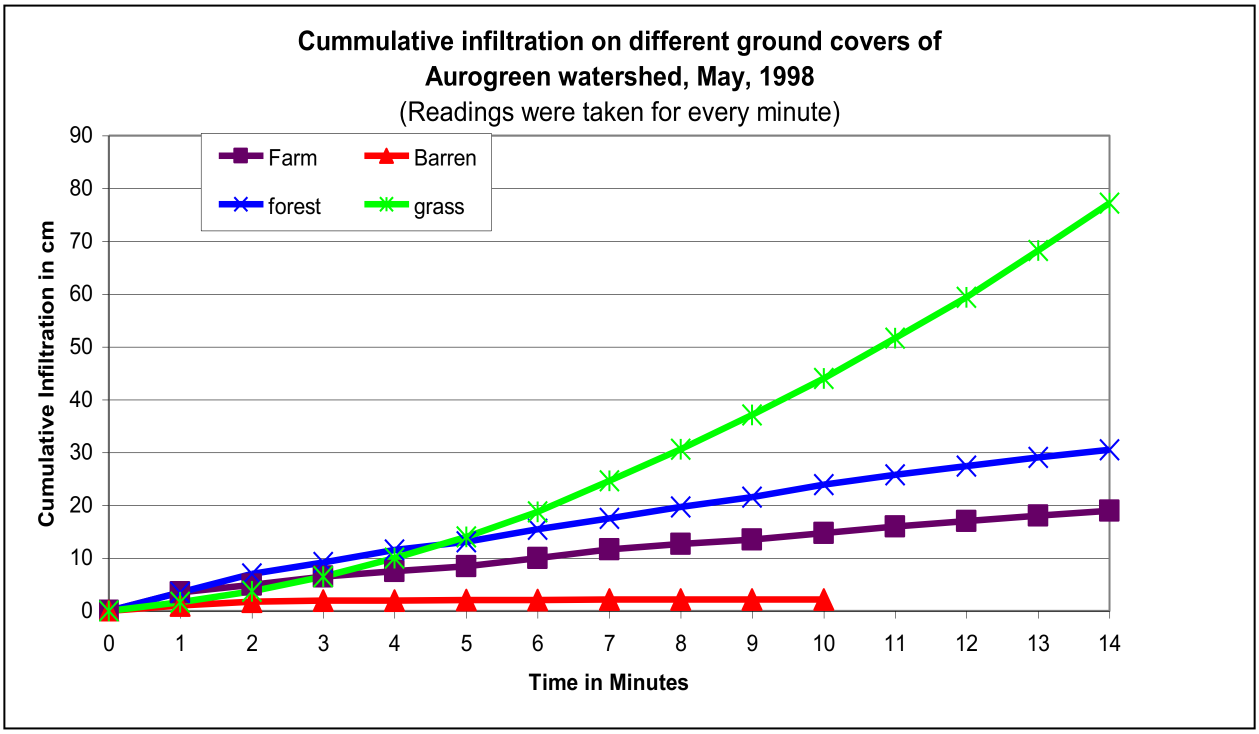
- To reduce the lost per evaporation and evapo-transpiration
- To limit the runoff as much that possible
- Facilitate the infiltration

1. TO REDUCE THE LOST PER EVAPORATION AND EVAPO-TRANSPIRATION

Concerning the lost per evaporation and evapo-transpiration, our Auroviliens specialized in forestry are actually building-up the required knowledge to offer proper green covering and low lost by appropriated species. It must be noted that the positive impact of such an approach is multiple.

- Reducing the lost per direct evaporation, because of the relatively lower temperature below the canopy.
- Reduction of lost per evapo-transpiration, the selected species being far less demanding in water and less sensitive to high temperature.
- Increasing the infiltration rate. See the following graph.
- Increasing the potential rainfall pattern. It is a known effect of forest on micro climate fluctuation. See the following graph

Several infiltration tests done over the last years in different place of Auroville show the impact of grass and tree on infiltration



2. TO LIMIT THE RUNOFF AS MUCH THAT POSSIBLE

3. FACILITATE THE INFILTRATION

A rudimentary estimate of the future runoff situation, with the city area covered at 45% with building, road and others facilities, as foreseen in the last master plan, provides the following information according to world wide standard:

City area runoff coefficient 0.60 Greenbelt runoff coefficient 0.20
General runoff coefficient 0.30

	Surface sqm	Equivalent received rain cum	Lost by evapotranspiration cum	Runoff & infiltration cum
City area	4,908,739	6,342,090	4,841,380	1,539,845
City area with green belt	19,634,954	25,368,361	19,365,519	6,159,379

According to these standard figures we can presume that the **maximum** part of the rainfall feeding really the water table will be **6,159,379** cum per year (24% of the initial figure) for the City and the Greenbelt. The following analysis is showing that we can improve this result.

4. RUNOFF IN THE CITY AREA

The most challenging part concerning runoff control is obviously in the city area: covered areas (roads and vicinity, buildings, industrial estate) are known to generate a runoff of 90%.

Today, the foreseen density parameters for the entire city area are of 45% of constructed area. This will anyhow fluctuate from sector to sector according to the activity. We can imagine easily that the foreseen high-density area of the residential zone will offer little space for infiltration. On the opposite, the cultural zone or the low-density area of residential zone, or even more the parks, will offer plenty of space for infiltration. Otherwise, the soil permeability is changing a lot from place to place: areas are gravely, others lateritic, and others clayish.

Therefore, different solutions would be required to target the different situation.

An important and conditioning choice refer to the general strategy of surface water management.

One of the actual proposals is to develop a very large lake around Matrimandir which, apart of others aspects, may act as a collecting point, a storage space and a temporization infiltration device. This, to work, must relay on a very complex infrastructure to collect the runoff from all over the Auroville plateau and to pump it to this lake. We can easily imagine the complexity of such an infrastructure. But to maintain the lake as it is envisaged will require anyhow a very important flow of water every year, and therefore imperviousness would be required to achieve it. It must be noted that the very unpredictable rainfall pattern (as explain above) may generate a very poor quantity of water available, and therefore challenge the usefulness of such a complex proposal.

We can summarized the different options as follow:

- Infiltrate locally as much than possible, which relay on multiple infiltration devices, very decentralized system, with a possibility of minimizing the drainage infrastructure toward zero
- Concentrate and collect the flow and pump it at a suitable place for further and delayed infiltration
- A combination of both

It is understandable that the best(s) solution(s) should be flexible and manageable, as much that sustainable and affordable. It is then clear that localized studies must be conducted, with an open panel of solutions, suitable for each case. One monolithic solution is therefore not relevant.

A lot of brainstorming about architecture, roads and town planning must be put together to target a low figure runoff and to avoid overloading the drainage structure (if and where required), and waste this very valuable resource. .

As an example, the roads as proposed so far ("Pre-study of different types of roads and related topics", Cristo, May 2001) are of impervious type. Around 24 kilometers of road are foreseen in the city area, which will generate 227,000 m2 plus extra space requirement for shoulder, drainage, parking spaces, rotaries, and other infrastructure will generate an important runoff (90% of the rainfall, to compare with 80% for a mud road). The choice of such roads is linked again to multiple factors, mainly circulation density and kind of vehicles using these roads. We can therefore assume than other fields of development, as style life and circulation facilities, generate indirectly the runoff impact from the road. It is easy to imagine than light vehicles require smaller road and less strengthening work, so more percolation rate. Anyhow, the main difficulties may come from the concentration effect and the acceleration effect.

At this stage, it is recommended to investigate in different possibilities, like self-infiltrating roads, on top of the very valuable proposed solutions.

Concerning infiltration devices, some of the small-scale percolation systems within the city area present a very promising efficiency and need to be further experimented on a larger scale. Our own observations and further information coming from abroad indicate that shallow systems are more efficient than deep one. This mainly because of strengthen sealing effect of clay or microorganism (main sealing agents) under more important water pressure.

The best solution to allow quick and safe percolation seems to create percolation devices allowing a relatively small storage height (around 1 meter), based on a vertical large pit filled with draining materials as sand, the percolating surface including the pit and the drainage area must be then planted with grass. The grass has the double advantage to greatly enhance the soil permeability and to create aerated volume above and the surface, allowing slow particles sedimentation and quick microorganism degradation, and therefore less cloaking effect and important self-recovery of the permeability rate.

We anyhow assume than Auroville will be able to reach a run-off 15% for the city area.

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We can presume that the real part of the rain available for ground recharge will be **9,500,000 cum** per average year for the City area and the Greenbelt.

One of our major concerns about infiltration techniques is to avoid any degradation of the groundwater quality by infiltration of toxic elements. Special care about hydrocarbure and pesticide must be foreseen, as we are far to be eco-friendly (on Auroville plateau) in term of transport, and mainly in term of pesticides. These last pollution products have a very long lifetime and can have impact on the aquifers for years even after full stop. That is why the commonly used infiltration well, strongly recommended by local authority, seems very interesting but very dangerous if not very well done.

5. RUNOFF IN THE GREENBELT

The work done so far for water conservation in the green belt shows that we are today able to reduce the runoff to nearby zero in some areas of greenbelt itself, which is very encouraging. The main difficulty is coming from the slope on the East and South part with the existing canyons. For the time being, the control structure localized in the canyons are main done for erosion control, and even if it enhance largely the control of the runoff, they have a limited impact on it.

To generate the same low figure systematically, the difficulty is to create greenbelt continuity all around Auroville's plateau, which is a financial problem (to purchase the land), but a practical one too: the west part of Auroville for example is very much suitable for agricultural activities, and as such can be used for on field recharge but not to handle eventual runoff from the city area. An important part of the drainage of Auroville area reaches already the western side of the plateau, collected in Irumbai Tank.

On the other hand, the soil permeability is very different from one area to the other, because of the different composition of it: mostly sandy in the North, East and South, clayey on the West and part of the North side. This generates different surface or subsurface run-off scenarios, and eventually very different water table impacts.

Geographical specificity can generate very important local fluctuations in the runoff condition: canyons for example.

> We can presume that **the Greenbelt will generate a runoff coefficient of 0.05** (5% of the rainfall) as an average, which can be really considered as an achievement.

G. ACTUAL WATER CONSUMPTION IN AUROVILLE: THE DARK PART

The **60 wells** presently well known in Auroville show an average daily consumption of **3,772 cum**, which means a yearly water consumption of 13,76,748 cum, or an amazing **daily average consumption per capita** of **2,514 lcd** (918 cum/c/y). This last data is subject to caution, and require a full consumption investigation. Anyhow, according to the methodology of the survey at that time, it must not be very far from the ground reality.

As a comparative figure, the average word water consumption (recommended for a sustainable lifestyle by UNO) is estimated to be 1000cum/c/y, including everything, with 70% for agriculture purpose, 20% for Industrial use, 10% for domestic use.

Water Consumption in India in Billion Cubic Meters

	1990		**2000**		**2010**		**2020**		**2025**	
Domestic	25	5%	33	5%	40	5%	48	5%	52	5%
Industry	15	3%	45	6%	75	9%	105	11%	120	11%
Energy	19	3%	34	5%	49	6%	64	6%	71	7%
Irrigation	460	83%	549	79%	637	76%	726	74%	770	73%
Others	33	6%	34	5%	35	4%	36	4%	37	4%
Total	**552**		**694**		**837**		**979**		**1,050**	
Consumption/ capita /year in cum	642		694		727		753		750	

Evolution of water consumption for India till 2025

Nevertheless, we are very far to be self-sufficient. Today, Auroville is very little developed, as far as food production and industries (main water consumers) are concern (probably less than 10% today). Similarly Auroville is not and will not go for heavy water consuming technologies.

This shows us that we have today a very bad misused of our common water resources, despite all the work done in this field since the true beginning of Auroville.

According to surveys done on water consumption, we can assume the average consumption is dispatched as follow (in liters):

Domestic use	industries & commercial activities	Public use & waste	Total Municipal Consumption	greenwork & agriculture	Total
300	150	200	**650**	1,864	**2,514**

NB : Much probably, a very important part of greenwork and agriculture use is going in fact for landscaping and should be totalized within public use. Otherwise, domestic or even industrial wastewater is often reused for gardening after treatment.

By taking in account the projected population of Auroville (50,000 people), the actual average water consumption will lead to **125,700 cum/d**, and obviously much more by taking into account the neighboring population.

At the same time, the water resources are diminishing drastically all around the area and the intrusion of seawater is a proven fact, even inside Auroville.

We urgently need to know what are our real resources, to understand the way water is used in Auroville, and to improve it. Our collective future depends on this vital source.

The following part of this document will assert the evolution strategy of water use in Auroville and the followed path leading to efficient and sustainable water management.

H. WHERE WE ARE

It is interesting to see that the actual full capacity of Auroville pump wells (24h pumping hours per day) is above 17,000cum/d, theoretically enough to supply the full project municipal consumption according to good water consumption standard, and even much more with proper water reused. But the geographical positioning of wells does not fit in a realistic way with this figure.

One of the first data required is to position on a map the wells, and to study what are the potential areas for supplementary good wells.

These first figures and the following water consumption tables show clearly than Auroville is and will not be depending on is own (geographical) resources, as far as water is concern: even by using 100% of water available, it will not cover more than one fifth of the required amount. And these data doesn't show the local population living on the same area.

We actually share the water as common "goods" with a very important population (not clearly define) because of the landscape of the area and the geographical limits of the aquifers (apart of the first aquifer of Auroville plateau). This means a factual common responsibility with the surrounding population as far as water resources, quality and pollution are concern. Any general water management must be done according to the physical and sociological reality. The concept of a limited area purposefully oriented is far from the ground reality. Studies and proposals must be therefore defined with a very strong educative component, oriented both within and outside Auroville.

The following table shows how far we are in term of water extraction in the surrounding area.

The villages on Auroville area as such are printed in blue.

Village	Number of wells 1996	Av daily extraction (1996)	Population (1995)	Consumption/ cap./ day (cum)	Consumption/ capita/ year (cum)
Allankuppam	21	2,050,618			
Auroville	129	4,023,209	1,500	2,682	979
Bommayapalayam	250	5,647,650	3,138	1,800	657
Chinna kottakuppam	37	16,717,800			
Chinnamudaliarchavady	44	1,459,350	812	1,797	656
Edayanchavadi	70	979,474	2,245	436	159
Irumbai	23	601,498	560	1,074	392
Kotta medu	10	2,358,100			
Kottakarai	41	1,130,434	672	1,682	614
Kottakuppam	126	2,474,150			
Kuilapalayam	10	1,985,642	2,256	880	321
Periyamudaliarchavady	34	861,450	1,136	758	277
Pillaichavady	10	1,548,537			
Rayapettai	25	2,986,541	560	5,333	1,947
Sanjeevi nagar	12	1,967,556	1,093	1,800	657
Total	**842**	**46,792,008**	**13,972**	**3,349**	**1,222**

According to these data, 265 wells extract an average of 9,119,658 liters per day for a population of 4,977 people in Auroville area.

I. WHERE WE GO

To supply the city as such, 20 good wells (20cum/h average capacity) will be required, this without back used of water. According to our actual knowledge of the situation, this challenge is realistic within the city area and the closer part of the greenbelt, which seems a good choice, both technically and economically. This estimation is a valuable one only if the above-mentioned pollution, scarcity and salinisation difficulties are properly handled. Otherwise, we will have to face the degeneration of the situation. That is the main unknown factor, together with the result of the actual global warming, which can lead in our area to even quicker salt intrusion in the aquifer.

Today, at least 12 wells offer the required profile, and 3 very good other potential plots (above 20cum/h) are already identify.

The other possible choice includes a pumping station west of Mudaliyarchavadi, a very good natural drainage area, but with the related risks due to the localization on the coastal zone, the direct impact of over-irrigation in this area, the proximity of Pondicherry and the resulting pollution risk.

The green belt area is more difficult to analyze, because of the not clearly define future land use pattern. But already, the prospected west area of Auroville, well adapted for agriculture activities, is relatively heavily used (as far as water consumption is concern) because of the village activities (mainly agriculture) and the usual water strategy.

J. AN OVERVIEW OF SURFACE AND WATER REQUIRED FOR FOOD SELF-SUFFICIENCY

As self-sufficiency for food production is one of the purposes of Auroville as defined by Mother, it is interesting to see what does it means in terms of surface requirement and potential water consumption.

Stating than the actual rice production is about 1,000 Kg/a. in organic farming, but should reach at least 1,500kg/a in the nearby future, according to improvement of agricultural techniques and soil fertility.

A population of 50,000 people eating 0.150kg of rice per day (one meal) 300 days per year will require: 50,000x0.15x300=22,50,000kg or 2,250 tones of rice per year, or 2,250/1.5=1,500 acres (600 hectares) of land for rice growing only. Because of the rotation techniques, the same lands can produce the required grams, millets and groundnuts. On top of what, vegetables, cattle and fruits will required an important supplementary area.

For example, milk production will require:

8 liters per day per cow (actual average daily production) can feed 25 people (this is a relatively high figure). This means that 50,000/25=2,000 cows are required for the full city, with 1 acre per cow required to feed it, means 2,000 acres. That is a clear example why we must go for vegetable protein.

Assuming around 2,000 hectares required for food self-sufficiency, this surface is actually only partly define in the required Auroville master plan proposal …

From these data, we can envisage that the water consumption for irrigation and farming purpose should be between 12 millions and 20 millions cum per year.

K. EVOLUTION OF WATER CONSUMPTION FOR THE CITY AREA

The actual domestic water consumption in Auroville is between 125lcd and an amazing 450lcd, with an average of 300lcd. This is however difficult to be sure of the real amount, because of the generally unclear separation between domestic water and other purpose (gardening for example). Comparatively, the standard in the surrounding villages is around 15lcd. An in depth study is required to understand why we reach such a general consumption rate: lifestyle, spreading of the housing, wastes?

It is however needful to define the targeted water consumption, reusable part and ground water requirement, then the progressive evolution from the actual situation to the final stage of development and subsequent environmental impacts, and finally the foreseen strategies, planning and technical tools to develop and reach such results.

1. DEFINITION PARAMETERS OF WATER CONSUMPTION

According to our actual complex reality, we presume that our situation will improve relatively slowly, mainly according to the concentration of the population. A proper water management will be then much more easy to settle, both for distribution, reuse and separation of water lines according to purpose and quality. This will generate an important impact on general water consumption and the possibility of sustainability. On the other hand, Auroville is actually going for an occidental lifestyle (as air conditioning systems), which includes a higher rate of water consumption. Lets hope for the best …

The retained figures are close to the average ones for Indian cities without heavy industries.

- Public use is defined above standard, because of the very important green surfaces in the city area, and the care we have for common facilities.
- On the opposite, the wastes part is lower than the Indian standard (15%), thinking of the good technical level, “perfection in physical”, that we all go for.
- The reusable part is assumed to be very high, this according to the already good knowledge we have about wastewater management and the ongoing effort to improve it.

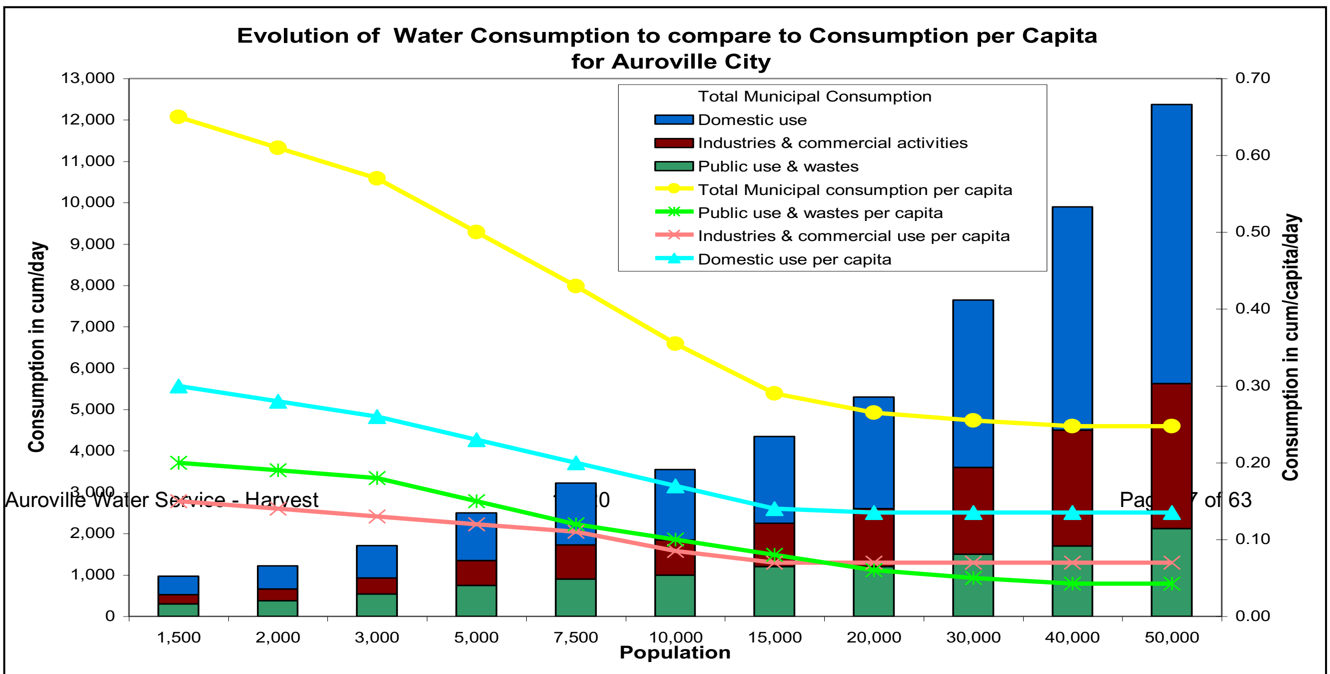
The actual consumption for industrial and said commercial use is very hypothetical, because of the non-significant size of our actual industrial setups and the very largely sprayed users.

We target the average consumption for Auroville in the future as follow:

	Consumption lcd	Reusable part %	Reusable part lcd
Domestic use	135	80	108
Industrial use	50	70	35
Commercial use (factories, offices, hospitals, hostels, restaurants, schools)	20	80	16
Public use (gardening, park, road, public fountain)	20	0	0
Wastes (10%)	23	0	0
Average Municipal consumption	**248**	**-**	**159**

2. ESTIMATED PROGRESSION OF WATER CONSUMPTION

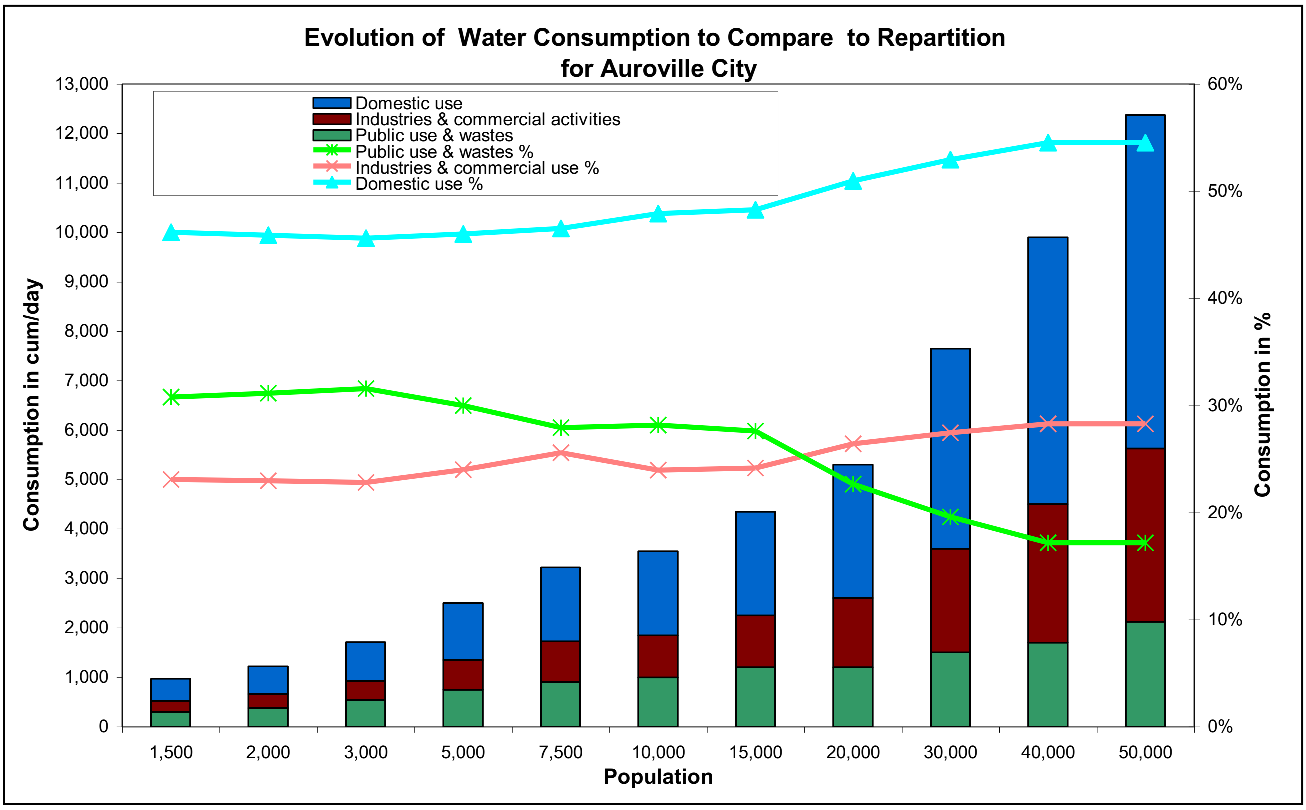
The following graph gives an estimated progression of the water consumption for Auroville city, starting from the actual situation, the anticipated progressive



changes and the final above targeted criteria.

The total municipal consumption is anticipated around 12,375 cubic meters per day and 4,516,875 cubic meters per year for the final population of Auroville (50,000 people).

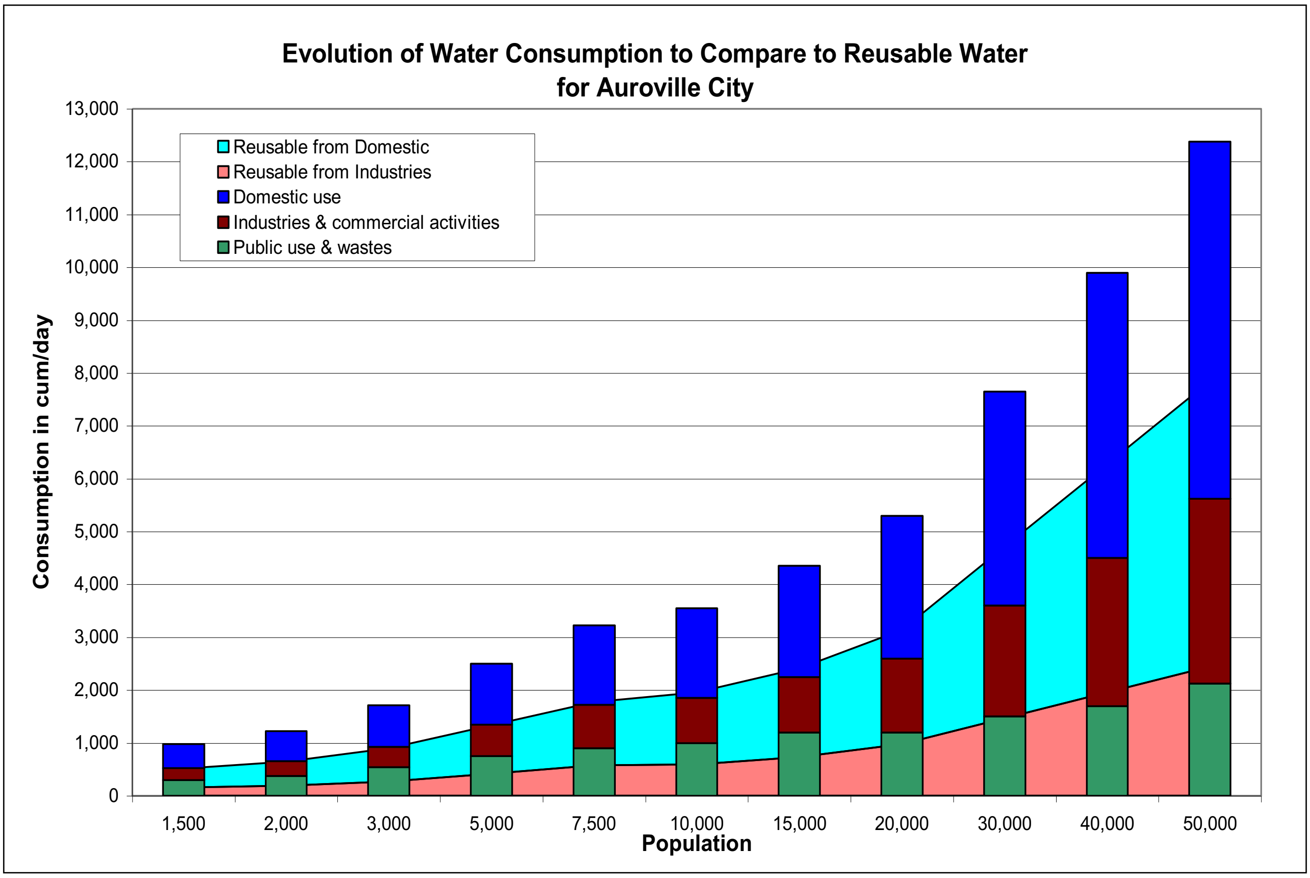
As shown below, the evolution will not concern only the quantity of water consumed, but the repartition too, which will lead to a proportional transfer from the public users to the other consumers, mainly the domestic users.



This evaluation has been done according to the fact that Public use and Waste (as defined paragraph K1) does not require important amount of water if properly conceived, and therefore can lessen according to evolution of the infrastructure.

3. ESTIMATED PROGRESSION OF REUSABLE WATER

According to the population growing and the evolution of the infrastructure, a substantial amount of water can be reused for different purpose



We can therefore assume that from the 12,375 cum of water required daily, 8,025 cum should be reusable.

There further considerations required according to the final use of this reusable water. The water for domestic use must be fully safe, apart of toilets use (~30lcd or 1,500cum/d for the full city). The reusable water can then contribute fully for public use (2,125cum/d), partly for industrial purpose (estimated to 35%), so 1,225 cum/d, the other part requiring clean or even drinkable water quality), the rest being suitable for agricultural purpose, providing sufficient safety.

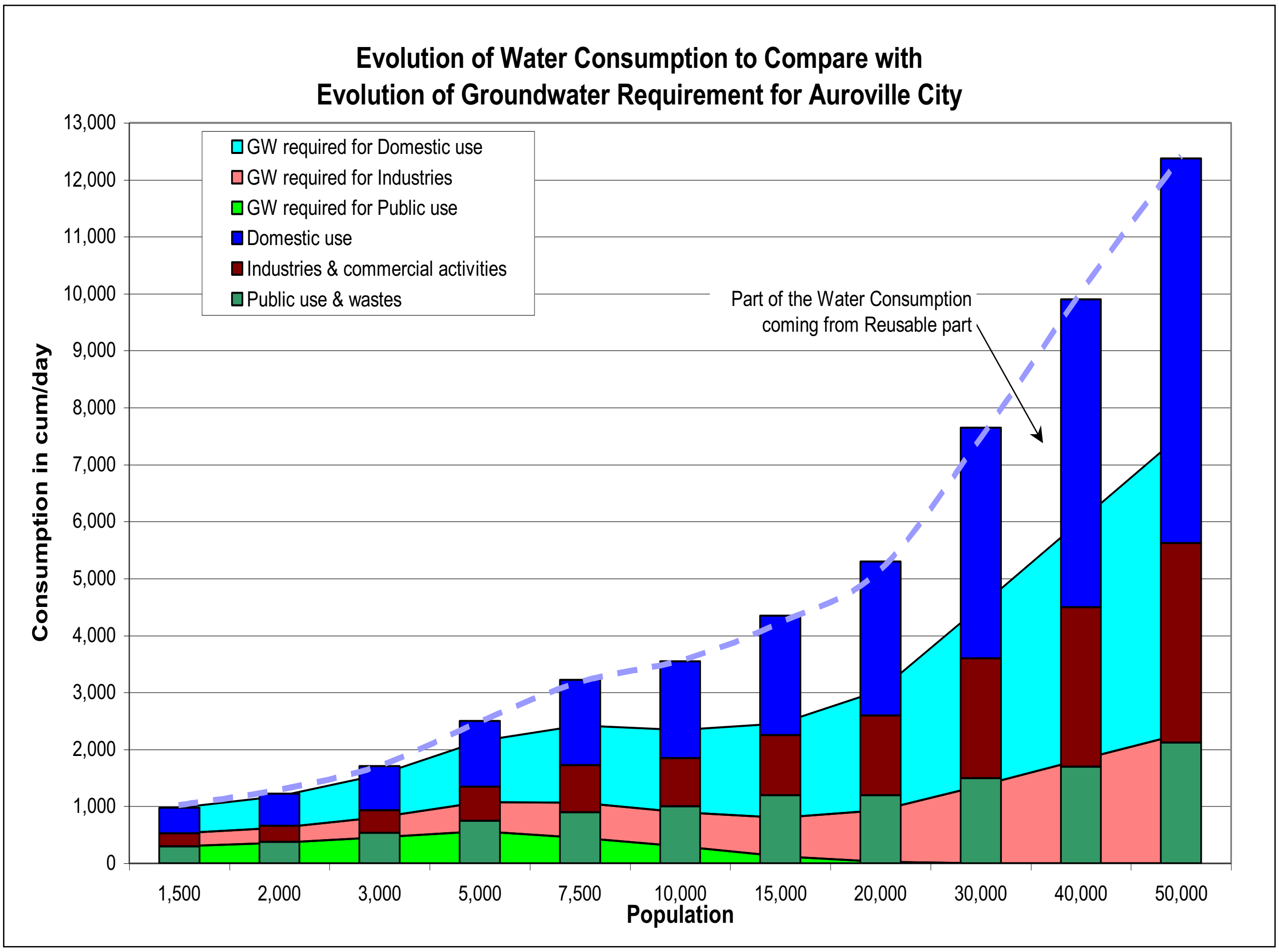
Therefore, we are able to define the requirement of Ground Water for the City area.

4. REQUIRED WATER PRODUCTION AND WELLS CAPACITY FOR THE CITY

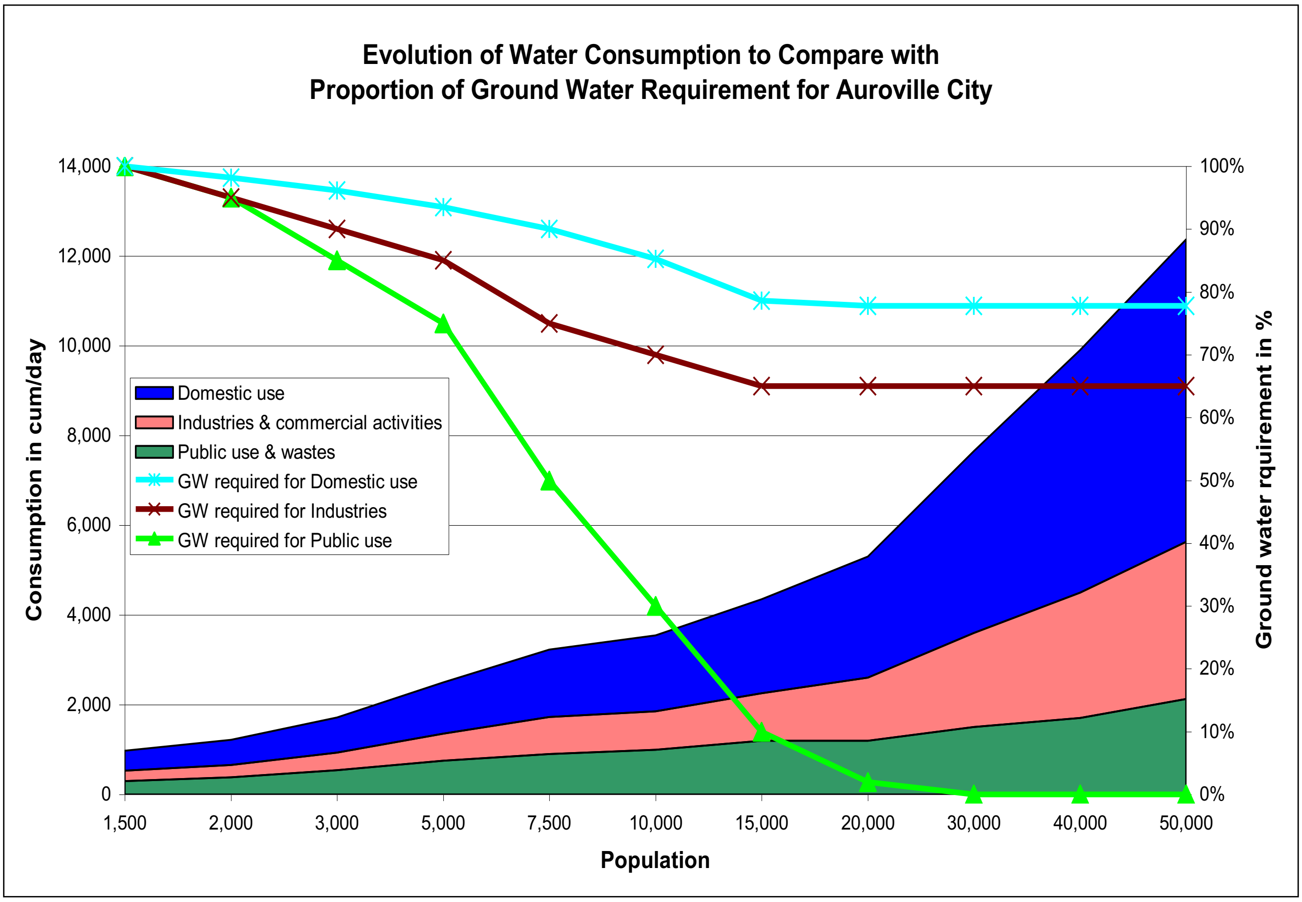
From above analyses, we can assume that from the total water consumption in the city area, around 4,500cum/d can be reused for municipal purpose, 3,000 cum/d for agricultural and green-work purpose on a daily average.

> Consequently, the city area must be feed with an average of 7,525 cum per day (say 8,000 cum/d) or 2,920,000 cum/y, of ground water, providing proper distribution and treatment efficiency.

This defines the above-said minimum 20 good capacity wells required with enough security margins: 20cum/h*20*24h=9600cum/d.



The following graph shows how the evolution of water consumption, distribution and reuse pattern will affect the different grounds water requirement.



L. RAINFALL HARVESTING

M. WASTE WATER MANAGEMENT

There are 3 ways to think a bout wastewater management.

1. CENTRALIZED SYSTEM

The most generally wastewater management implemented in the world is by centralized wastewater collection and treatment system.

The raw water is collected as it is, then sent to a properly designed treatment unit, then eventually reused. It results in lowest plant construction cost per treated volume. But to connect individual sources to the treatment unit may cost 5 times more. The management required highly qualified manager, but little in number. Maintenance is very high because of sophisticated equipment requiring permanent care.

One of the main difficulties of this concept is because of byproduct generated in sewer, generating very bad odors and quick degradation of ducts. As the sewerage passes through the mains sewers and pumping stations, the effluent becomes an incubating culture with the production of a variety of fermentation products including hydrogen sulphide and ammonia. The composition of the sewerage effluent is continuously changing during its passage and is significantly affected by the action of microorganisms, which are present in large numbers in cultures attached to the walls of pipes and other structures over which it passes. Aggressive atmospheres, which continually damage the pipes, pumping and other equipment consequentially, accompany the resulting mixture of material.

One of the traditional methods of combating the negative impacts of hydrogen sulphide has been the injection of oxygen to long rising mains. However, the cost of it is very important. This is a very well proven fact happening everywhere in the world and more especially under tropical conditions. For example, New Delhi is facing severe degradation of sewer of 10 years old only. The approach of fully centralized system seems not to be a sustainable one.

2. DECENTRALIZED SYSTEM

The second way is to use fully decentralized system. This needs an environment able to absorb the discharged wastewater wherever it is. In city area, this means using each free square meter for wastewater treatment purpose. Because of the very good biological and chemical activity of soil in tropical country and low input design, this can be very efficient in certain conditions. That is why public toilets using soak pits as been so successfully used everywhere in India.

The structural cost can be low, especially if substandard treatment is accepted, which can be possible for low concentration of population. The maintenance of such a concept, if to be secured, require supervision, central coordination and service organization, for proper maintenance and sludge disposal for example. This can however easily leads to health hazard dissemination and as such is not recommendable for Auroville. The reuse of water is not easy.

As long as the problem is concerning toilets only, there is a large scope for dry toilets, soak pits, and so on.

But the problem changes totally if to consider washing water for example. It is well known that washing water contain as much biological contaminant than toilet water.

> The central difficulty of wastewater management is not the solid part, it is the polluted water.

3. SEMI CENTRALIZED SYSTEM

The last way of wastewater management is by semi-centralized system. This means to connect several smaller treatment units (primary and/ or secondary) to sewerage of smaller size (no settlable mater), with eventually a tertiary or final common treatment. Construction costs are relatively low but require qualified management of each system and of the overall structure. The advantage is the important cost saving for the sewer because of the quality of the water, the possibility to adds modules according to he development, and eventually the reuse of the water just at the production level.

4. FEASIBILITY

As Auroville wants to go for a high standard of water use efficiency and for sustainable technology, an appropriated way must be define. This should include deeper understanding of wastewater management and know-how. The fact is that to continue to develop large filter bed or high land consuming technologies will generate a problem of land availability. On the other hand, to go for the actually widely sprayed technologies using heavy mechanical and chemical techniques imply high equipment cost, running cost and maintenance. On top of what it can generate a lot of back product very difficult to handle.

It is therefore very advisable to go for biotechnologies: Auroville experiment has largely show the sustainability of it. Questions are still there for eventual heavy pollutant factory, specially implying heavy metals or chemicals agents.

According to general data, the required area must fluctuate from 1 to 20sqm per cum of wastewater for an equivalent pollution level and according to the technology used.

Primary treatment can easily be done per sector and sub-sector. Secondary treatment requires still a lot of research and understanding to lessen the size as much as possible and to identify systems which does not require electrical power (as one of the sustainability criteria), at least for the process as such. The tertiary treatment is not automatically required, depending of the use of treated water.

There are already several well-known technologies fitting with these criteria and for some allowing both primary and secondary treatment level, as baffled reactor, trickling filter or UASB for example.

Very promising information are coming from EM technology. The concept is based on the insemination of Efficient Microorganisms as pre-treatment. This means that EM will act through the full sewerage system. The pre-treatment process makes use of the alternation between anaerobic and aerobic conditions, which occurs in a piping network to begin some of the processes otherwise reserved for the treatment plant. This allows the development of a partially self-sustaining culture of competitive microorganisms throughout the collection network, which would reduce the production and release of hydrogen sulfide and ammonia. At a certain level, this technique would promote a change in the overall process of putrefaction of waste and allow a partial breakdown of organic material in the waste without the usual negative by-products, as fat built-ups or clogging effect, which can result in important maintenance and cleaning cost. Auroville produce already his own EM.

The following table gives very interesting information from collated effluent quality data from Beaconsfield (Australia) collection system using EM technology from June 1998 to March 1999.

	1998							1999		
Indicator	16 Jun	24 Jun	1 Jul	8 Jul	15 Jul	29 Jul	17 Aug	3 Feb	10 Feb	30 Mar
TSS mg/L	284	307	366	260	254	269	287	200	139	126
COD mg/L	647	614	879	617	560	600	508	409	362	340
BOD mg/L	224	255	347	266	228	264	213	--	212	150
TKN mg/L	83.1	88.8	91.3	47.2	79.8	81	--	33	34.5	29.9
NH3 mg/L	--	67.1	38.7	36.8	--	--	51.9	25.2	27.5	23
PO4 mg/l	9.19	8.92	9.5	6.39	8.88	9.44	7.99	6.15	5.59	1.51

It is easy to anticipate that further benefits in terms of reduced augmentation costs at the Sewerage Treatment Plant will arise from the ability to deliver at least partially treated effluent from the collection system itself.

An in depth study is anyhow required to define the most effective way to use it.

N. URBAN DISTRIBUTION CONCEPT

The galaxy concept, together with the geographical shape of Auroville area and Mother indications, gives a predefined way to water distribution, from the center, Matrimandir area, to the outside.

The general collection, distribution and back use piping systems are therefore envisioned as fitting in the general layout.

From the existing overhead tank of the residential zone, whatever useful it is for the time being, it is not recommendable to multiply such huge and bad looking structures which are then avoided in the actual proposal.

Apart and eventually below the Matrimandir decorative lack, a chain of underground tanks can be installed, offering enough capacity and margin for supplying the population and activities going on in the city area. Because of this strategic and compact location, the control and maintenance of the overall installation will be facilitated. Each tanks or groups of tanks will be attributed for different water quality (drinking water, clean water, reuses water, rain water) and different activities area (residence, parks and gardens, industries…) and be built and fitted consequently.

To avoid bad esthetical impact from overhead structures, it is envisaged to feed waters with suitable pressure by pressurized lines, either by a simplified overhead tank integrated to existing building and/or by pressurizing pumps. In the first case, the overhead tank(s) will not offer storage capacity but only provide enough and equalized pressure, and therefore can be reduced to a very minimum size. The main difficulty with the second solution is to supply power all over the year to the required pumps, which is not anymore a problem of water as such. The advantage of the first solution is the easiness to provide power backup while the advantage of the second is no esthetical impact.

The piping will follow the natural tendency: one first ring near the inner ring road, a second ring on the outer ring road, a set of interconnection from the inner to the outer ring road following the main road, and sub-distribution systems in the sub-areas.

1. DRINKING WATER

Because of the very low quantity of drinking water required per day and per capita I to compare to the general water consumption (3 to 5 liters per capita per day , so 150 to 250cum per day for Auroville's population), and because of the ongoing result of drinking water quality at every tap in occidental countries, it is envisioned to not provide specific water system for dinking water, but to offer localized purification facilities, then micro distribution system.

Generally speaking, the drinking water will be supplied by the fresh water system, which should therefore offer enough safety, cleanness, taste an odor.

2. FRESH WATER

The water pumped in the aquifers can be collected and stored in multiple underground tanks (to guaranty safety) localized in the outer garden. They must offer a 3 days consumption storage capacity, say 24,000cum according to above figure. These tanks can be built and linked together in a modular way according to population growing. A proper sizing is envisioned as 6 tanks of 4000 cum, each of them being divided in sub-tanks to provide enough facilities for maintenance and safety.

From there a properly designed pressurized distribution system can provide water to the full city area, this to avoid huge and unaesthetic overhead tanks. This is the actual way (when possible) to deal with water municipal distribution. This approach is most probably less costly than multiple overhead tanks.

From there, and according to the variable density of population, the 2 ring roads should be the natural way for the main distribution ducts: circular and sufficiently sized to allow further development. This closed distribution system will allow regular pressure everywhere, and continuous delivery when maintenance is required on one point of the loop.

3. WASTEWATER

Wastewater should follow the same concept, but because of the treatments required needs deeper analyses.

The general concept is to treat water as much as possible locally, and then to send it to polishing areas, mainly for UV exposure and destroying pathogen agents. In this view, it is interesting to note that very important drop in E.Coli content in raw water occur when EM are inseminated through the sewer net.

The two most interesting solution, possibly combinable, are to collect the treated water in green belt south part, nearby the city area because of the natural slope, or to collected it in the surrounding lacks of Matrimandir. From there, the same path (not pipe!) than clean water can be followed to supply required water wherever needed for gardening or other purposes.

For polishing, the advisable depth to maintain good UV exposure is maximum 90cm for a period of 10 days. Afterward, the storage place can be deeper. This means that the required volume for polishing the water must be around 80,000cum (8,000cum x 10 days) or an equivalent surface of around 90,000sqm (9 hectares). The bad side effect of this kind of wide-open lake is the important lost of water by evaporation. The lost can be as high than 155,880cum per year (427cum/d, 5% of the daily wastewater production) from a yearly wastewater production of 29,20,000cum. This should be largely moderated by a proper EM insemination concept for example, allowing deeper lake and a corresponding lesser loss.

Whatever the part of it around Matrimandir, the regular production of wastewater will allow a constant level of water in the lack, so to maintain esthetical area and water plants growing. The shape of lake can be done according to any kind of aesthetic, providing facilities for maintenance (algae or floating plants harvesting for example).

4. FIRE LINE

A special attention must be given for fire line equipment. The easiest way to deal with it should be by putting in place dry lines following the same way than clean and wastewater, and connected to several medium capacity underground tanks equipped with high pressure pumps, and themselves connected to “green” water line. With a properly design network, the distance between fire tanks and any points must be small enough to provide fire security every were.

All together, the water paths will include: drinking water (blue), gardening and other purpose water (green), wastewater (gray), and fire dry line (white). It is possible and advisable to conceive a common underground channel hosting these different activities.

5. RAIN WATER

We don’t think advisable to collect it in network, but to collect and percolate it at a very local level. To provide properly designed and sized storage tanks in the city area will means very high expenses for anyhow very short storage capacity. On top of that, it would mean a very good follow up water quality because of the normally high organic water content of harvested rainwater.

Properly designed percolation area could be provided everywhere needed, which would means a detailed landscaping per area. If properly done, such devices can be very aesthetic and have a very high percolation rate (grass planted, correctly define depth, light side slope, surrounded by trees,…).

O. AUROVILLE WATER SERVICE - HARVEST BACKGROUND

Started in 1982, Auroville Water Service has been progressively involve in all these evolution, developing at the same time an in depth analyses, know-how and vision about the general situation of water in our area. Because of an expending awareness of the multilevel implication of water mater, on either scientific, technique, sociologic, biologic and philosophic levels, the actual programs organized by AWS are covering very large area of human activities and has very large scopes.

Main tools of AWS to acknowledge Auroville water situation is by the day to day involvement in all kind of installation, maintenance, development, research program and follow-up of the totality of water devices in Auroville and on a large scale in the bioregion. AWS is involve in water management, harvesting, infrastructure, piping, underground scenario, wastewater management and by-products, organic farming and dissemination, lab analyses, GIS integration… Because of is leading position as water consumption understanding, landscaping effect and pollution impact, AWS is hosting a multiple research and development program in organic farming and dissemination, in collaboration with others Aurovilian groups and outsiders organizations.

In 1996, following the alarming change of water quality in the area, a database has been started as a tool of investigation, including very broad information on around 900 wells of Auroville and the surrounding area, and the used of pumped water. At that time, Auroville owned 200 wells. A part of general, technical and administrative information, this database include data on an important set of wells for which we have the lithology, allowing an in depth study of the geology of our area and a general overview of our groundwater resources. An in depth work is going on today to update this database on Auroville (which totalize now around **250 wells**), have a day-to day updating process and put the data under a data processor, with a GIS link.

125 wells sprayed on Auroville's area are monthly checked for proper follow –up of the water tables evolution and salt intrusion scenario.

Weather data are also available on a 90 years period, with a 10 years period from Auroville area itself, which allow conducting in depth analyses of weather evolution and impact on the area. Auroville Water Service is now hosting a total weather station.

AWS water management programs are strongly fitted on the social component, the key factor of any sustainable development. Therefore, the acquaintance of the socio-economic impact of water reality and evolution is more and more acknowledged, as much as suitable possibility to create participative ways to manage water resources with the surrounding population.

We can therefore assume that we are able to propose a clear vision of Auroville water reality, and from this strongly required knowledge a general model of water management for Auroville.

P. REQUIRED FOLLOW-UP AND STUDY

To understand where we are in term of water resources and use, and why we are so high in consumption level, the following works are required:

1. Up to date data about the about 900 wells from the surrounding area, including:
   - Village, Community, Owner's Name, Location No, Code No
   - Age of well, Well altitude, Well Depth (m), Well type
   - Casing (Size), Casing (Depth), Casing (slots), Casing (material), Casing (filter), Drilling method, Pipe size (inches)
   - Static water level (summer), Static water level (winter), History of water level, Draw down, Aquifer (s), Core samples
   - Pump type, Pump power (fuel type), Motor power (HP)
   - Av hrs of pumping, Av hrs for Summer, Av hrs for SW monsoon, Av hrs for NE monsoon, Av hrs for Winter, Out put per hour, Av daily extraction, maximum capacity
   - Use of water
   - Top soil description, Geological description
   - Crop irrigated (perennials), Crop irrigated (annuals), Crop irrigated (seasonal), Irrigation method
   - Water quality (taste), Water quality (color), Water quality (salinity), Water analysis done
   - Test needed
   - Notes
2. Integration of data from Auroville Water Service: ref. of the well, depth, dia., type, lithology, localization, conditions, pump capacity…
3. Regular field work: positioning by GPS, well's capacity (compression), standard analyses (Ph, conductivity,…) water level, consumption follow-up, installation of hour meters,…
4. Definition of a grid of piezometric wells (for example with a spacing of 500m), monthly survey

   Integration on GIS with 3D analyses for underground cone of depression, modelisation of spatial evolution, pollution risks modelisation (roads, polluting industries, wells security area), link between wells and hydrogeology …