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A Water Management Concept for Auroville

From today's situation toward the future:
A scalable approach

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AN INTEGRATED MANAGEMENT OF WATER RESOURCES IN AUROVILLE

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Years after years, countless information, researches, 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 information 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.

Abstract

Since the early days of Auroville, the water situation in the City of the Future and its surrounding followed an in depth evolution on multiple levels:

☞ 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, a definitively very high figure!

☞ 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 complete run-off to an extremely limited one today: this amazing improvement in surface water and percolation management is the result of years of landscaping, soil conservation programs 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 infrastructures are operational.

☞ From totally wild wastewater management to numerous sustainable systems: Auroville is today recognized as one of the most demonstrative place for decentralized wastewater management in Asia.

☞ From a "do it yourself" situation to an international 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 changed completely since Auroville's birth. The already severely threaten lands and water are today dreadfully endangered. The main aquifer of our area dropped of 40 meters, and an alarming extending salty groundwater his now mapped out in large part of our bioregion, menacing crops, a major part of drinking water for the villages and finally the survival of this blessed region.

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.

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.

Some Thoughts on Sustainability

Sustainability

"Meeting the needs of the present generation without compromising the ability of future generations to meet their needs."

Brundtland-1987

"A sustainable society is one that lives within the self-perpetuating limits of its environment. That society is not a "no growth" society - it is, rather a society that recognizes the limits of growth and looks for alternative ways of growing."

James Coomer

"Leave the world better than you found it, take no more than you need, try not to harm life or the environment, make amends if you do."

Paul Hawken

"If you get right down to it, sustainability is really the study of the interconnectedness of all things".

Barbara Lither

"Sustainable design is the careful nesting of human purposes with the larger patterns and flows of the natural world... "

David Orr

Environmental Sustainability

Although Environmental Sustainability is needed by humans and originated because of social concerns, Environmental Sustainability itself seeks to improve human welfare by protecting the sources of raw materials used for human needs, and ensuring that the sinks for human wastes are not exceeded, in order to prevent harm to humans. Humanity must learn to live within the limitations of the biophysical environment. Environmental Sustainability means natural capital must be maintained, both as a provider of inputs (sources), and as a sink for wastes. This means holding the scale of the human economic subsystem to within the biophysical limits of the overall ecosystem on which it depends. Environmental Sustainability needs sustainable consumption by a stable population.

On the sink side, this translates into holding waste emissions within the assimilative capacity of the environment without impairing it.

On the source side, harvest rates of renewables must be kept within regeneration rates.

Non-renewables cannot be made sustainable, but quasi- Environmental Sustainability can be approached for non-renewables by holding their depletion rates equal to the rate at which renewable substitutes are created.

An expanded definition of Sustainability

By looking at the above citations and definitions, it is clear that the very concept of sustainability is far to reach the goal of Auroville, because it focus mainly on preserving and remediation, and very little on positive impact.

Since early days, Auroville have generated positive impact, at least in some areas like environmental matters and to a certain extend in education. It is clear also that today Auroville is not a city. Therefore, the challenge to create a sustainable city, and even more a "positive" city, is still in front of us. In this area as in many others, we can only witness that there is no sustainable city in the world. A new way has to be open: that is the task in front of us.

A strategic frame to integrate economic, social and environmental factors, but also other fields like cultural factors and quality of life issues in the orientation and policy decisions, is needed. The need for equity, in Auroville's zone of influence, routes toward an integrated development approach of larger beneficiary impact circle than Auroville's own population.

Seven strategic imperatives for sustainable development in Auroville

- ⇒ Stimulating growth
- ⇒ Changing the quality of growth
- ⇒ Meeting essential needs for jobs, food, energy, water, and sanitation
- ⇒ Ensuring a sustainable level of population
- ⇒ Conserving and enhancing the resource base
- ⇒ Orienting or reorienting technology and managing risk
- ⇒ Merging environment and economics in decision-making.

Each of these points required serious reflection. As they define the basic of Auroville development, it is suggested to investigate them in depth to define the guiding principle of our progression.

The attention now given to the idea of sustainability in the world reflects growing documentation and recognition that many types of social, economic, and environmental problems are interrelated, and that only a broad, integrated approach will yield truly effective policies and results.

Sometimes the term sustainability is used in a narrower sense, such as when an environmental group focuses solely on environmental sustainability, forgetting the financial and social side, or when a group of interest focuses on its need to ensure that a new power station or a water system will be implemented and continue to function long past completion of its planned development project. This has led to confusion and contradictions, even at the level of international sustainable development declarations.

We can only hope that similar practices have and will have no place in Auroville, keeping discernment and impartiality as essential means of Auroville life.

Sustainable city

There are many definitions of 'Sustainability', but the generally accepted strap line is that *'a sustainable city is a city that works so that all its citizens are able to meet their own needs without endangering the well being of the natural world or the living conditions of other people now or in the future' (*Creating a Sustainable London. Sustainable London Trust, 2000).

This of course begs the question 'Who are all its citizens?', because there is no doubt that those leading the most consumption-orientated lifestyles, may well have to adapt to considerably less wasteful ways to meet their individual resource requirements in future.

The Principles

The important principles of sustainable development and regeneration that should be met are:

- Social progress that recognizes the needs of everyone, particularly the less advantaged;
- Prudent and responsible use of natural resources, seeking to reduce waste as much as possible at all stages of provision, transportation, consumption and disposal;
- Effective protection of the environment;
- Maintenance of handle able levels of economic growth and employment.

Wider Influences

We also have to recognize the wider influential factors played by:

- Continued population expansion and increased stress on scarce resources;
- Rising standards of living and aspirations, in Auroville as well as in the surrounding villages;
- Cultural differences in the use and value of resources (water, electricity, vehicles);
- The finite resource of fresh water globally available at an affordable price;
- Climate change.

Unsustainable Cities

"The major problem of remaining within the ideal framework of sustainability is that the modern city or urban conglomerate, as it has developed over the last millennium is essentially an unashamed consumer of resources which extends its 'eco-footprint' of demand far beyond its own boundaries engaging extensive areas of land and numbers of people to service it. The average UK eco-footprint in the year 2002 is 6.29 hectares per capita. To serve all earth's inhabitants on an equal basis would take a planet with three times the cultivatable area of Earth. The City as it stands, is therefore essentially an unsustainable social organism.

"The objective therefore is to draw urban consumption patterns fair to everyone into line with more sustainable aspirations, by balancing reasonable demand with availability, and hence taking steps to achieve a more sustainable city

.

"This in itself is no easy task since the lifecycle of the city as an independent organism evolves far slower through time than the cycle of the generations that live within it. This is

equally applicable to changes in water use and sanitation as much as other aspects of city life.

"Furthermore, it is essential to recognize, that water services are only part of the picture. Sustainability criteria apply not only to the built environment, transport, infrastructure, development, energy use but also to the economic and political institutions of a city."

Integrated Water Management as a Tool for Sustainable Urban Regeneration
Chris Shirley – Smith Director, The Metropolitan Water Company, London (UK)

Integrated Water Management

Alternatives to mains tap water

• Tankwater	• Stormwater
• Greywater	• Treated effluent
• Dams	• Artificial lakes

Integrated Urban Water Cycle Management is based on the philosophy of appropriate utilization of the urban water resources, matching the types of water usage to the quality of the water source. E.g.:

- **Water treated to drinking standards primarily restricted to human consumption and those activities associated with direct human contact (e.g. bathing);**

- **Stormwater and grey water reuse should be the primary source of water for garden and landscape irrigation and toilet flushing respectively.**

This section is attempting to devise and deploy a integrated and therefore better managed use of the water resources which are available within an intensely stressed environment. This will involve taking the following steps:

- Long term planning for the future;
- Engaging of local communities in open discussion about expectations;
- Ensuring strong, consistent political and regulatory leadership;
- Identification of funding sources for research and infrastructure development;
- Greater imagination in 'water resourcefulness' (intelligent use of water);
- Setting of best practice examples for planners, developers, contractors and architects, local and regional authorities, financiers and entrepreneurs in projects to follow.

It is not merely by coincidence that the majority of the cities of the world are located within accessible reach of natural water sources which historically have provided both a source for clean water for consumption, and as often as not a sink for the discharged effluent. As urban populations have grown disproportionally to the available sources and sinks both upstream and downstream, new solutions have had to be sought with the sourcing of fresh water and the disposal of effluent reaching ever further afield and widening influence on the surrounding natural environment, incrementally enlarging the 'eco-footprint'.

Anyhow, the initial condition of Auroville was and is not alike: to offer easiness from the start seems not to be in Mother views, but well to create appropriate conditions for experimentation and to find replicable solutions out of significant difficulties!

From this perspective, we can consider ourselves as particularly blessed, as we cannot but witness the work ahead. It is a great advantage if you compare to ordinary situation where human beings get most of the time aware of problems when it is already damageable.

Minimising Environmental Impact

Water providers have usually the statutory duty to provide water and wastewater services to customers irrespective of the wider implications of their actions, and divorced from sustainable planning constraints or procedures. The spotlight has recently been turned on these very environmental implications.
A significant amount of energy is consumed pumping both clean and polluted water relatively long distances to service urban areas. That energy also is a finite resource and has a cost. Hence the sustainable integrated water management must also take into account the reduction of energy usage, which must be achieved in the collection, distribution, recycling and disposal of water and wastewater.

Integrated Water Management focuses on minimizing environmental impact by the most efficient use of appropriate sources of water and its considered after-use disposal through :

- Appropriate quality of water(s) for the requirements of the customer/ user
- The widespread application of conservation measures to reduce primary use;
- Developing appropriate applications of the reuse and local recycling of water;
- Protection of receiving waters from the treated wastes.

The elements that need to be coordinated through such a strategy are:

- Essential Services – Potable water, and non-potable waters derived from surface or subsurface sources;
- Waste water treatment and disposal. This includes recycling of wastewater.
- Rainwater harvesting
- Drainage which includes stormwater management and flood management;
- Amenity features – lakes, canals, green spaces and public area cleansing.

It is only if and where all of these aspects of water service provision can be coordinated that maximizing water use can be achieved. The in charge water “company” must be an integral and participating member of all planned urban activity and development - part of the planning process rather than ‘a supplier’. And above all sufficiently flexible to be able to respond to current requirements, within the frame of larger ones.

Clearly therefore, even as certain generalized principles may be applied to Integrated Water Management, the details and specific balance of appropriate management are likely to be highly site specific depending on:

- The availability of resources locally;
- The relative balance between economic, hydraulic and environmental efficiency of large and small scale systems in the area;
- The reasonable balance between imported, existing and locally available resources.

One question remains: does sustainability equate to self-sufficiency? This should be addressed at very local level as well as at intermediate and large scale.

One of the normal duty of a communal water agency is to be responsible for setting and enforcing targets for improvements in the water distribution and waste water collection sectors, especially with a view to eliminate leakage in the supply networks and to minimize pollution from leaked effluent sewage in the waste water networks. Leakage from both is usually widespread (up to 40% and more in India) since original systems do not received the investment they require to maintain their integrity.

The case therefore for sourcing water close to the point of first use and the reusing of this water at least one further time before disposal has three advantages:

- Reduction of energy costs in pumping;
- Alleviation of the load on existing infrastructure (less leakage);
- Reduced requirement to provide and maintain major infrastructure.

Nonetheless, the value of standard infrastructure network should not be underestimated. While Integrated Water Management and sustainability concepts advocate for decentralized approach, the conventional mains and sewer network may prove to be the most sustainable solution in some area. While a detailed evaluation per area is required to come to valuable conclusion on most appropriate choices, it seems already clear that a supple combination of various techniques and methods will constitutive a truly appropriate solution for Auroville.

Green Cluster

A sustainable water supply should incorporate that there are a wide range of applications in modern urban living for which water of an inferior quality may suffice.

The obvious examples of this are toilet flushing (where 'western' practices form the norm for the transport of human and animal excreta), public amenity cleansing, irrigation, the washing of vehicles and significant quantities of industrial water stock.

Furthermore, there are the additional choices of using recycled green water for non-potable uses and rainwater harvesting, either as a separate supply or blended with green water. Parallel to and integrated into this cycle is the requirement to manage drainage of surface water in a suitably attenuated manner to avoid flash flooding and to maximize the irrigation potential of such water.

If this opportunity is fully exploited in the most cost effective and integrated way, alongside 'sustainable' and energy efficient buildings, then we begin to approach a comprehensive Integrated Water Management system.

Water and sustainable economics

None of the above makes any sense nor will it ever attain public acceptance unless it can be demonstrated that such 'sustainable' systems will provide a viable economic return for a given investment.

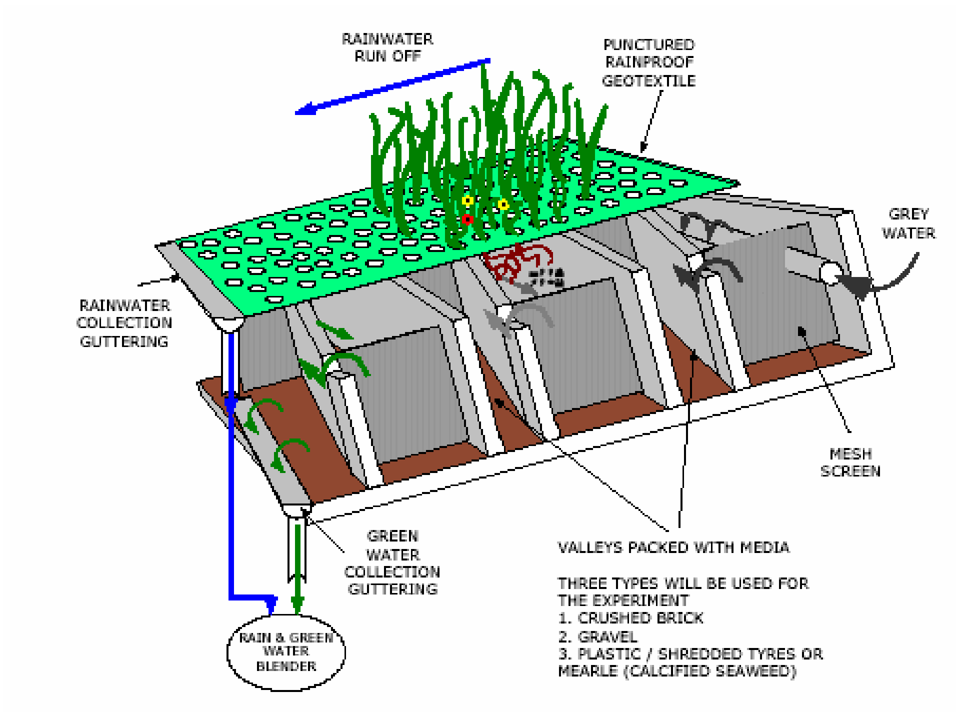
Suffice it to say that the economic approach to sustainable and integrated regeneration requires to be 'holistic' and takes whole life-cycle costs into account including the wider environmental implications of resource development which would be required for new buildings or activities were it not for the local sourcing and in-situ recycling of water.

It is also perfectly clear that the dual criteria of local sourcing and targeted water quality as the main planks of an integrated water management system cannot be other than cost effective in the long run.

Multi-utility supply as a sustainable option

Another valuable tool in the deployment of integrated infrastructure in an urban environment is the single trench multi-utility system, wherein all or the majority of the infrastructure services (including electricity and phone) are laid parallel in one trench in the street or pavement. Not only is this arrangement more economical to install and maintain, but it also reduces disruption to traffic at any future date when the trench might – for whatever reason – require reopening. This approach is minimizing capital outlay and maximizing profit potential.

Component example: Green Roofs



Structure of Green Roof and Rainwater Collection

The above Green Roof design is specifically devised to recycle 'grey' water in situ by using the roof space on multi storey building to maximum advantage. Used grey water is collected from domestic baths, basins and showers in the block to a sump, is filtered and pumped to the roof where it is allowed to trickle through a root zone system acting as a cleansing medium. The treated effluent is then blended with separately collected rainwater, and re-supplied as a n fitting resource ('green water') for the flushing of toilets and the subsurface irrigation of gardens and green spaces. In this way the cost of water is kept to a minimum to residents of denser areas. It also represents a significant saving in energy and highly treated drinking water, and contributes beneficially to the local microclimate and visual attractiveness of the area.

Ref: Structure of Green Roof and Rainwater Collection - . The Metropolitan Water Company

Conclusions

Integrated Water Management presents a positive contribution towards the correct thinking of the provision of water and wastewater services, which both stimulates and is stimulated by the generation of an ecological city area.

It also crucially involves the full integration of water services with planned sustainable development because it:

- lowers the cost of resource provision
- reduces the quantity required
- facilitates greater local control
- promotes positive thinking, enhanced education and water awareness

The adoption of such strategy by all planning authorities in conjunction with water and waste water suppliers is recommended as an appropriate option for all new development as a major contribution to sustainable urbanization.

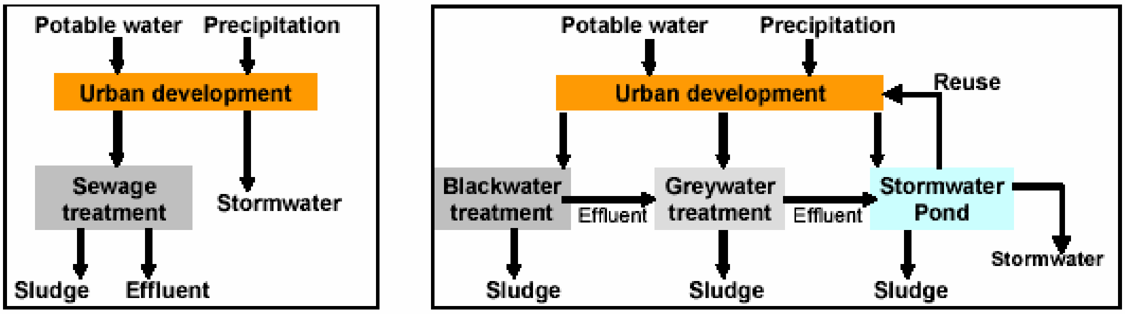


Figure 3: Base case and decentralised stormwater and wastewater utilisation system

Ref: Integrated Urban Water Cycle, Andrew Speers, Grace Mitchell

Integrated Water Management is also part of a deeper reflection on the achievability to integrate urbanization in an ecosystemic way, which will then include natural ventilation, landscaping, noise control, air quality, mobility concept, human and nature interaction… this in the city context but also in relation with various scale of regional development.

Sustainability Principles for Urban Infrastructure

A general guiding principle for designing innovative urban stormwater management systems is that they promote sustainable development.

The following principles are suggested for sustainable infrastructure systems:

1. Individual urban activities should minimize the external inputs to support their activities at the parcel level: for water supply, import only essential water for high valued uses such as drinking water, cooking, showers and baths. Reuse wastewater and stormwater for less important uses such as lawn watering and toilet flushing. Minimize the demand for water by utilizing less water intensive technologies where possible. For transportation, minimize the generation of impervious areas, especially directly connected impervious areas, for providing traffic flow and parking in low use areas.

2. Minimize the external export of residuals from individual parcels and local neighborhoods: For wastewater, export only highly concentrated wastes that need to be treated off-site, i.e. sludge. Reuse less contaminated wastes such as shower water for lawn watering. For storm water, minimize off-site discharge by encouraging infiltration of less contaminated stormwater and using cisterns or other collection devices to capture and reuse stormwater for lawn watering and toilet flushing.

3. Structure the economic evaluation of infrastructure options to maximize the incentive to manage demand by using commodity use charges instead of fixed charges: For water supply, assess charges based on the cost of service with emphasis on commodity charges. Charges should be a combination of a level of service that specifies flow, quality, and pressure. For wastewater, assess charges based on the cost of service with emphasis on commodity charges. Charges should be a combination of a level of service that specifies flow and quality. For stormwater, assess charges based on the cost of providing stormwater quality control for smaller storms and flood control for larger storms. Charges should be based on the imperviousness with higher charges for directly connected imperviousness and the nature of the use of the impervious areas and their pollutant potential. Some charge should be assessed for pervious areas. Credit should be given for on-site storage and infiltration. For transportation, assess charges for transportation related imperviousness directly to users as fees per kilometers for travel and fees per hour for parking in order to encourage demand management and switch to more sustainable modes of transportation.

4. Assess new development for the full cost of providing the infrastructure that it demands, not only within the development, but also external support services.

The following list of other goals provides additional criteria for more sustainable new communities. These topics overlap and can be consolidated down to a much smaller set of principles.

1. Re-develop vacant or low-density development within currently developed areas at higher intensities.
2. Design comprehensive, mixed-use neighborhoods instead of isolated pods, subdivisions and developments. The spaces between neighborhoods should consist of functional open space such as gardens, parks, playgrounds, bikeways, jogging trails and the like.
3. Encourage telecommuting and the infrastructure necessary to make it work.
4. Do a comprehensive accounting of infrastructure costs that reflects social and environmental costs as well as economic costs. Current investments based on partial and incomplete accounting systems are considered to be factors in urban sprawl and the inability of infrastructure capacity to keep pace with these urban development patterns.
5. Develop a community designed for people first, that does not damage the natural environment, that enables a healthy and active lifestyle, where human interaction is an everyday event (Goldstein 1997).
6. Housing, stores, and employment will be accessible (less than 20 minutes) to each other by walking, biking and transit (Goldstein 1997):
7. With regard to environmental impacts, the City of Dreams will have the following benefits (Goldstein 1997):
    a. *Reduce energy demand by 75%.*
    b. *Reduce freshwater use by 65%.*
    c. *Reduce solid waste by 90%.*
    d. *Reduce air pollution by 40%.*

Much general information on this subject is available on the Internet, (e.g., see $martGrowth Network-. smartgrowth. org).

Sustainability and Optimal Size of Infrastructure Systems

While the notion that “bigger is better ” still persists even in Auroville, some argue that these systems are not sustainable. Problems with larger systems include:

1. Large organizations are necessary to manage these systems.
2. Large organizations with monopoly powers tend to be inefficient and less responsive to changing needs.
3. Complex cost sharing arrangements need to be developed to fairly charge each group for its share of the cost of the system.
4. Part of the savings associated with regional systems results from transferring problems from area to area so as to take better advantage of the assimilative capacity of the receiving environment. While such solutions may reduce costs overall, they may be highly objectionable to citizens in those parts of the service area that receive a

disproportionate share of the negative effects of such transfers,(e.g., added flood hazard ,traffic noise, more polluted water).

5. Large systems are inefficient if recycling of treated wastewater and stormwater is desired since it is necessary to pipe and pump this water back through the entire system.
6. The failure of larger systems causes more serious consequences since larger areas are affected and illicit discharges are concentrated at fewer points.
7. Customers are less aware of the nature of the problems that they cause and are therefore less receptive to their responsibility to better manage their demand for the service.
8. The strong tendency for urban sprawl that has accompanied the creation of such systems makes them even less efficient due to the added distribution costs associated with more dispersed development.
9. It is necessary to build large amounts of excess capacity into these systems. Thus, the existing customers pay this added cost. The primary beneficiaries of this largesse are new customers. Correspondingly, the governing agency has a strong incentive to promote the growth of the area to help pay for this unused capacity.
10. Regional systems serve a heterogeneous group of customers including domestic, commercial, and industrial users. Thus, the nature of the wastes is harder to predict and the design must be upgraded accordingly. The use of a regional system encourages off-site discharge of wastes instead of prevention or treatment at the source.
11. Once established, it is difficult to restructure large organizations who enjoy monopoly power to provide the infrastructure service.

Given the above concerns, one of the main themes of this description is the need to rethink this basic "bigger is better " premise that has guided water infrastructure development during the past 50 years and is today trying to find is way in Auroville too. Perhaps, bigger is not better.

Components of Urban Land Use and Stormwater Problems

Southworth and Ben-Joseph (1997) provide a history of urban streets, a critique on current practices, and project the expected nature of streets in urban areas. They estimate that, worldwide, more than one third of all developed urban land is devoted to roads, parking lots, and other automobile infrastructure. In the urban U.S., about one half of the land is used for this purpose. In automobile oriented cities like Los Angeles, the percentage increases to two thirds (Hanson 1992, Renner 1988).

Streets have the potential to play a major role in stormwater management. Walesh (1989, Chapter 5) presents an analysis of the ability of a typical urban street, with curb and gutter, to temporarily convey or store stormwater runoff from major runoff events. Skokie, IL implemented an innovative approach to its streets by using them to intentionally convey and store stormwater in a controlled fashion so that combined sewers do not surcharge and back up into basements (Walesh and Carr, 1998).

Stormwater control is achieved in this cost-effective system using on-street berms coupled with catch basin flow regulators and, where needed, subsurface tanks.

Streets and Highways

Urban street patterns have changed during the 20th century, with the automobile having a major influence on street design at all levels.

1. It requires more paved area than necessary because all residential streets are built to the same specifications.
2. It requires more expensive type of pavement since the traffic is dispersed throughout the neighborhood and thus the streets must be designed to a higher standard.
3. This heavier traffic demand creates a hazard.
4. The gridiron layout is monotonous and uninteresting.

A hierarchical street pattern is recommended. For residential streets, curvilinear alignments, cul-de-sacs, and courts are more suitable.

Desirable design criteria

1. Layout should discourage through traffic.
2. Minimum width of a residential street should be 15m with 7m of pavement, 2.4m planting/ utility strips and 1.2m foot walks.
3. Cul-de-sacs are the most attractive street layout for family dwellings.
4. Minimum setbacks for streets should be 4.5m.
5. Front yard should avoid excessive planting, for a more pleasing and unified effect along the street.

These early FHA guidelines had a tremendous influence on residential development in the United States because of their financial leverage over developers and homebuyers. The Institute of Transportation Engineers (ITE) has also had a major influence on residential street design. Their perspective is heavily influenced by traffic flow and parking considerations. They recommend (Southworth and Ben-Joseph 1995):

1. Right of way minimum of 18m.
2. Pavement width of 10m..
3. Cul-de-sacs should have a maximum length of 300m with a 15m radius at the end.
4. Parking lanes should be 2.4m in width.

The influence of these street design standards on drainage and stormwater quality does not seem to have been a significant factor in the decision making process.

According to Khisty (1990), the use of 3.3m lane widths is acceptable in urban areas due to higher right-of-way costs. 3m lane widths are only acceptable on low speed urban streets.

Ewing (1996)divides residential streets into the categories of arterial, collector/sub-collector, and access. Four types of residential streets (i.e., non-arterials)exist. They are:
1. Collector
2. Sub-collector
3. Access-looped
4. Access-dead end

Transportation engineers tend to design streets to maximize convenience for the automobile subject to safety constraints. Recently, designers have attempted to recast the purpose of streets as multi-purpose components of the community with much more of a pedestrian orientation. Shared streets provide a multi-purpose use of residential streets. These streets have gained favor internationally.

Street Classification and Utilization

The Federal Highway Administration (FHWA) tabulates a variety of street related statistics that can be obtained on the internet at *http:/www.bts.gov/cgi - bin/stat/final_out.pl.* Results for urban areas in the United States are shown in Table 2- 16.The major traffic carrying components of the highway system constitute only about 9%of the road mileage in urban areas. Local streets that carry little traffic constitute the bulk of the mileage, nearly 70%.Parking is allowed on the lesser used streets; thus, most of the parking is associated with local and collector streets. While the interstates, freeways, other expressways, and principal arterial streets constitute only 9.1% of the miles, they carry 58%of the traffic. At the other extreme, local streets, constituting 69.5% of the street length, carry only 13.8%of the traffic. Thus, in terms of managing imperviousness, the lesser used local streets are the prime candidates for evaluating whether they could be reduced in size.

The results of Table 2-16 also suggest that the primary sources of traffic related stormwater pollution are the intensively used street systems. This may suggest a control strategy of providing more treatment for these intensively used streets. This much smaller impervious area may be more amenable to control than trying to deal with the entire impervious area of the city.

Table 2-16 :Street mileage in the U.S.

Urban	**Miles of road**	**% of urban**
Interstate	13,307	1.6%
Other freeways/expressways	9,022	1.1%
Other principal arterial	53,044	6.4%
Minor arterial	89,013	10.8%
Collector	87,918	10.6%
Local	574,119	69.5%
Total Urban	826,423	100.0%

Recommendations for Residential Streets

Southworth and Ben-Joseph (1997) recommend the following principles for future residential streets:

1. Support varied uses of residential streets including children 's play and adult recreation.
2. Design and manage street space for the comfort and safety of residents.
3. Provide a well-connected, interesting pedestrian network.
4. Provide convenient access for people who live on the street, but discourage through traffic; allow traffic movement, but do not facilitate it.
5. Differentiate streets by function.
6. Relate street design to the natural and historical setting.
7. Conserve land by minimizing the amount of land devoted to streets.

Contemporary texts on highway engineering do not deal with urban runoff problems. Khisty (1990) cautions of the need to evaluate air pollution and noise impacts as part of highway design. He doesn't mention highway runoff as a problem. Wright and Paquette (1996)describe conventional highway drainage design but do not discuss stormwater quality problems or the detrimental off-site impacts from highway runoff. The FHWA has sponsored several studies to address the issue of stormwater problems associated with highways. Young et al.(1996)present a detailed overview of highway runoff quality problems. For a more current view from FHWA on whether they consider highway runoff to be a serious problem, see http://www.tfhrc.gov/hnr20/runoff/runoff.html.

Streets and Stormwater Runoff

Whether residential streets are laid out in a grid-iron, curvilinear, or cul-de-sac format does not appear to have a major impact on the quantity of stormwater runoff per capita. The curvilinear and cul-de-sac layouts tend to have a larger impact per capita because of lower development densities. Schueler (1995)summarizes current national design standards for residential streets as shown in Table 2-17.Parking requires about eight feet of space and traffic lanes require about 10-12 feet per lane. Thus, streets with two way traffic and parking on both sides of the street would be 36 to 40 feet wide, if multi-purpose use is not incorporated in the design.

Average daily traffic (ADT) in vehicles per day is the common indicator of the utilization of streets for traffic. Schueler (1995)summarizes the expected traffic flow for various ADTs assuming 10 trips per dwelling unit per day and that the number of trips in the peak hour is 10%of the daily trips. The results are presented in Table 2-18 (Schueler 1995).As Schueler points out, for ADTs of 25 or less, it is reasonable to share parking and traffic lanes. Unfortunately, many cities have adopted regulations that require wide residential streets even in areas with little or no traffic.

Parking

The Institute of Transportation Engineers (ITE)recommends (Southworth and Ben Joseph,1995)that on-street parking lanes should be eight feet in width and that driveway widths should be a minimum of 10 feet for one car,with a 20 foot-wide curb cut (five-foot flare on each end).According to Shoup (1995),off-street parking space per vehicle ranges from 300 to 350 square feet per space. This square footage includes the space itself, the access aisles, and the entry, exit area.

Table 2-19 .Parking demand ratios for selected land uses and activities (Schueler 1995).

Land Use	**Parking Space Ratio**	**Used Range**
Single Family Homes	2 spaces/du	1.5-2.5
Townhouses	2.25 spaces/du	1.5-2.5
Professional Office	1 space/200 sf gfa	150-330
Hotel/Motel	1 space/guest room	0.8-1.25
Retail	1 space/250 sf gfa	200-300
Convenience Store	1 space/300 sf gfa	100-500+es
Shopping Center	1 space/200 sf gfa	150-250
Movie Theatre	1 space/4 seats	3.3-5
Gas Station	2 spaces/pump (and 3 spaces)	
Industrial	1 space/1000 sf gfa	500-1200
Golf Course	4 spaces/hole	3-6.5
Nursing Home	1 space/3 beds	2-4+es
Day Care Center	1 space/8 children	4-10+es
Restaurant	0-200 1 space/50 sf gla	0-200
Marina	0.5 space/slip	0.26-0.7+es
Health Club	1 space/100 gfa+es	100-150
Church	1 space/5 seats	4-6
High School	many diverse ratios	

Medical/Dental Office	1 space/175 sf gfa	100-225

Notes: du=dwelling unit, sf=square feet, gla=gross leasable area, es=employee spaces ,gfa=gross floor area.

- ✓ moving towards a non-toxic environment;
- ✓ improving health and hygiene;
- ✓ saving human resources;
- ✓ conserving natural resources;
- ✓ saving financial resources.

Introduction

Water supply, wastewater, and stormwater systems are explored in this chapter, first individually and then looking at them in an integrative manner. Key areas of potential integration of these three functions are in reuse of wastewater and stormwater to reduce the required net import of water for water supply. The literature review summarizes previous and on-going work nationally and internationally to develop more sustainable urban water management systems.

The leadership in urban water resources during the early years can be traced to the ASCE Urban Water Resources Research Council (UWRRC)headed by M.B. McPherson. With funding from OWRR and the National Science Foundation (NSF), the UWRRC sponsored research conferences and numerous research projects dealing with a wide variety of urban water resources issues. The early results are published in McPherson et al.(1968).They pointed out that:

A single aspect research approach is totally inadequate and, Indeed, is entirely inappropriate, for resolving multi-aspect problems. The former simplistic approach of regarding a unit of water as a fixed entity, such as stormwater, must be abandoned for that same unit at a different point in time will be categorized as water supply, recreation, esthetics, etc., perhaps several times before leaving a given metropolis.

The ASCE UWRRC defined urban water resources to consist of:

1.Urban water uses:
   Water supply (domestic, commercial, agricultural and for fire protection).
   Conveyance of wastes (from buildings and industries).
   Dilution of combined and storm sewerage system effluents and treatment plant effluents (by receiving bodies of water).
   Water-oriented recreation and fish management.
   Aesthetics (such as landscaped creeks and ponds in parks and parkways).
   Transportation (commercial and recreational).
   Power generation.

2.Protection of urban areas from flooding:
   Removal of surface water at the source.
   Conveyance of upstream surface water through the area.
   Barricading banks, detaining or expressing flow natural streams to mitigate spillover in occupied zones of flood plain.
   Flood proofing of structures.

3.Manipulation of urban water:
   Groundwater recharge.

Recycling of water.

4.Pollution abatement in urban areas:

Conveyance of sanitary sewage and industrial wastes in separate sewerage systems.
Interception of sanitary sewage and industrial wastes.
Interception and treatment of storm sewer discharges or combined sewer overflows.
Reinforcing waste assimilative capacity of receiving water bodies.
Treatment of sanitary wastes at point of origin.

5.Interfacial public services:

Snowstorm and rainstorm traffic routing.
Street cleaning scheduling.
Snow removal strategies.
Lawn irrigation conservation.
Air pollution control.

Sustainability Principles for Urban Water Infrastructure

With regard to urban development in general and urban water systems in particular, Grottker and Otterpohl (1996) list the following general principles for providing sustainable development:

For the same or more activities, use less energy and material.

Do not transfer problems in space or time to other persons.

Minimize degradation of air, water, and land.

Application of these principles to urban water systems yields the following principles (Grottker and Otterpohl 1996):

1. Minimize the distance of water and wastewater transportation.
2. Use stormwater from roofs, preferably for water supply, instead of infiltrating or discharging it.
3. Do not mix the human food cycle with the water cycle. Do not mix wastewaters of different origin.
4. Decentralize urban water systems and do not allow human activities with water if local integration into the water cycle is not possible.
5. Increase the responsibility of individual humans for their impacts on local water and wastewater systems.

Indoor Urban Residential Water Use

The results of the NAREUS project indicate an average indoor water use of 63. 2 gallons per capita per day (gpcd) with a range from 49 to 73 as shown in Table 3-1. Perusal of Tables 3-2 and 3-3 indicates that indoor water use does not vary significantly between winter and summer. Indoor residential water use per capita is quite stable in the United States reflecting the fact that indoor water use is for relatively essential purposes. These results are quite similar to previous studies of indoor water use. Based on a nationwide evaluation, Maddaus (1987)concluded that indoor residential water use averaged 60 gpcd. Studies of the expected value of wastewater into sewers likewise report an average of 60 gpcd. Toilets account for the largest percentage of indoor water use in all three studies followed by clothes washers, showers, and faucets. The basis for the results shown in these three studies is described below.

Indoor water use does not vary significantly over the year. Some daily variability occurs between weekdays and weekends. The hourly distribution of indoor residential water use is shown in Figure 3-5 (Harpring 1997). Peak usage occurs during the early morning hours of 7 am to 10 am. Most of this peak is due to toilet and shower use. Toilet flushing continues at a similar rate for the rest of the day and into the evening. On the other hand, showers are taken primarily in the morning. Peak clothes washing activity occurs from 9 am to 1 pm. In general, water use in houses declines during the middle of the day because fewer people are at home. Use increases in the evening as people return home and prepare dinner, and then reaches its lowest level between midnight and 6 am when people are asleep. Interestingly, the British studies show use during the early morning hours for dish and clothes washing. The explanation for this usage pattern is that customers are taking advantage of lower electric rates during these hours (Edwards and Martin 1995). A general discussion of expected future trends in indoor water use follows.

***Toilet Flushing** :*

Toilet flushing is the most regular and predictable of all of the indoor water uses with an average of 16.7 gpcd and a range from 14.2 to 20.7 gpcd.Residents and guests will use the toilets every few hours if they are home.

The only significant break in this pattern is during the night when people are asleep. Day to day variation in toilet flushing depends upon how many people are home at a given time. More people would be expected to be home on weekends and in the summer when school is not in session. Toilet flushing generates the black water that is the main source of pollutants at the wastewater treatment plant. The low variability of toilet use is good news from a design point of view since it is then only necessary to design for relatively small peaking factors. Also, low quality water can be used for toilet flushing. Thus, it is a good candidate for using reclaimed wastewater or stormwater.

Conservation options for toilets have focused on reducing the volume per flush from four to five gallons to 1.6 gallons which is mandated nationally in the plumbing codes. An important concern with regard to lower volume per flush is that people would double or triple flush. Based on a nationwide study of toilet flushing, Mayer et al.(1997)conclude that double flushing is a minor problem with low-flush toilets, occurring only about 6%of the time. Also, it does not appear that people will change their flushing patterns. British studies of the nature of toilet flushing indicate that only about 25 %of toilet flushes are to dispose of fecal material as shown in Table 3-4 (Friedler et al.1996).

Table 3-4 .Number of toilet flushes per day and proportion related to fecal flushes (Friedler et al.1996)

Flushes/day	Week Day	Weekend Day
Fecal related	0.87	1.09
Other	2.24	2.43
Total	3.11	3.52

The diurnal pattern of fecal related flushes indicates that the majority take place between 6 am and 9 am. Thus, the savings result from fewer gallons per flush and not fewer flushes per day. The associated pollutant load would remain constant; accordingly, the wastewater concentrations would increase. Some concern exists that odors from sewers would be further intensified with the implementation of water conservation (Joyce 1995).

The volume per flush can be reduced to 0. 5 gallons using pressurized systems. This technology may gain more widespread use in the future. Future toilets include the currently mandated low-flush (1. 6 gallons)and ultra low-flush (0. 5 gallons) conventional toilets. Johnson et al. (1997)describe an innovative toilet wherein feces and urine are collected in separate compartments. This toilet reduces water use and allows more efficient treatment of the two separate waste streams. Dual flush toilets are employed in Australia wherein the user selects whether to use more or less flushing water depending upon the need.

Clothes Washing

Clothes washers use an average of 14. 3 gpcd with a range from 10. 8 to 16. 3 gpcd. The traditional Monday wash day has been replaced by a more uniform pattern of clothes washing which is done throughout the day with peaks in the morning and early afternoon as was shown in Figure 3-4. More efficient clothes washers are expected to reduce water use per load by about 25 percent. The timing on clothes washing could be affected by electric or water utility rates, which provide time of day incentives and disincentives. As mentioned earlier, water users in Great Britain apparently wash late at night to take advantage of lower electricity rates.

Showers and Baths

Showers (11. 2 gpcd)are much more popular than baths (1. 2 gpcd)for all 12 cities in the NAREUS study. For Boulder, CO, the morning shower is the predominant time for this activity as shown in Figure 3-5 (Harpring 1997). The other peak in showering occurs during the evening. Showers are taken on a daily basis in Boulder. Thus, no significant variability occurs from day to day.

Drainage from showers can be used for lawn watering during the growing season of year. It is a significant source of reclaimable water and the timing of its entry into the wastewater collection system can be estimated accurately because the shower water is not stored during use. The main conservation option for showers is to use low-flow shower heads. Results to date indicate only limited reduction in water use since users did not set the older shower heads to the higher flow rates. Federal law mandates a maximum flow rate for showers of 2. 5 gallons per minute (gpm). Results of the NAREUS study indicate that most people set their shower flow rate below this level. Thus, conservation savings may not be that significant (Mayer et al. 1997). No significant change in duration of showers has been observed with the lower flow rate showers. Showers are also important as a major user of hot water.

Faucet Use

Faucet use includes drinking water, water for washing and rinsing dishes, flushing solids down the garbage disposal, shaving, and numerous other personal needs. Faucet use averages 9. 3 gpcd with a range from 6. 9 to 10. 5 gpcd. No breakdown among these uses is available although one can make educated guesses as to the amounts of water used for these purposes. Best estimates of actual drinking water use are in the range of 1. 0 to 2. 0 liters per capita per day with a mean of 1. 4 liters per day (Cantor et al. 1987). Garbage disposals add about one gpcd to total indoor consumption (Karpiscak et al. 1990). Faucet use requires the highest water quality because it is the potable water source. Overall, faucet use is a small proportion of total use, which suggests the possibility of separate treatment and distribution systems for this source. Also, faucet use is relatively common during the day so equalizing storage requirements are low.

Dishwashers

Dishwashers are a relatively minor water use and newer dishwashers are being designed to use less water to conserve energy and water. Present per capita water use averages only 0.9 gpcd.

Water Use for Cooling

For some houses, and for many commercial and industrial establishments, water use for cooling is a significant part of the water budget. Swamp coolers are used in the more arid areas of the United States. Karpiscak et al. (1994)estimate that residential evaporative coolers use about six gpcd in Tucson, AZ. Because of the relatively small number of houses using coolers, the average usage is quite low, only 0. 4 gpcd.

Outdoor Urban Residential Water Use

Whereas indoor residential water use is very constant across the United States and does not vary seasonally, irrigation water use varies widely from little use to being the dominant water use. Also, it varies seasonally. The 12 cities in the NAREUS are not a representative sample of the United States with regard to climate types. Also, the amount of natural precipitation that occurred during the study periods can have a significant impact on the results. Nevertheless, the results certainly suggest the potential major impact of irrigation on average and peak water use.

A detailed evaluation of irrigation water use as a potential reuse of urban stormwater is presented in Chapter 8. This section only introduces the subject. Irrigation water use follows a definite pattern of high use rates in the morning and evening with low use rates during the day and late at night. Thus, these customers are following the common recommendations to not water during the middle of the day. Watering late at night is discouraged because of the noise from the sprinklers.

For the entire NAREUS study, outdoor water use averaged 82. 8 gpcd, significantly more than the indoor water use of 63. 2 gpcd. Studies of overall residential water use in Boulder and Denver show that outdoor water use averaged over the entire year exceeds indoor water use. Thus, outdoor water use can be a significant component of total annual average water use.

For the NAREUS study, Waterloo, Ontario is representative of conditions in the northeastern part of North America. During the summer, the outdoor water use averaged 25. 3 gpcd compared to indoor water use of 62. 3 gpcd. As expected the outdoor water use became negligible in the colder months, averaging only 1. 5 gpcd in October.

At the other extreme, outdoor water use in Las Virgenes, CA averaged 299 gpcd, nearly five times the indoor water use of 61. 6 gpcd during the summer sampling period. Thus, for residential areas in the more arid and warmer parts of the country, lawn watering is the largest single use on an annual average basis and is the dominant component of peak daily and hourly use during the summer months.

In the arid areas, evapotranspiration requirements are much greater than natural rainfall. In warmer parts of the country, even those with abundant rainfall, such as Florida, irrigation water use rates are high because of the long growing season which includes some dry periods. Irrigation water use is a major input to the urban water budget during the growing season. A growing number of people are installing automatic sprinkling systems. These systems tend to use more water than manual systems (Mayer 1995). Also, the timers on these systems are seldom adjusted. Thus, lawn watering occurs even during rainy periods. Experience with soil moisture sensors to control sprinkling use has been mixed. Automatic sprinkling systems do offer the potential for more efficient use of water if they are properly calibrated and operated (Courtney 1997).

The hourly pattern of total residential water use (indoor plus outdoor)for Boulder, CO is shown in Figure 3-5 (Harpring 1997). The study period from late May to early June included some rainy days. Peak hourly use between 6 and 8 am is caused predominantly by irrigation. Comparison of Figures 3-4 (indoor only)and 4-5 (total) indicates the importance of irrigation. The indoor water use at 6 am is about 7. 5 gallons per house while the total water use at the same time is about 41 gallons per house. Thus, irrigation constitutes over 80%of the peak hourly use.

Options for reducing outdoor water use include using less water-loving plants, applying water more efficiently, reducing the irrigated area, and using nonpotable water including stormwater runoff and treated wastewater (Courtney 1997). Irrigation use has an indirect effect on urban runoff because it causes much wetter antecedent conditions, which increases the portion of rainfall that runs off. Sakrison (1996)projects a potential decrease of 35%in the demand for irrigation water in King County, WA if the higher density urbanization occurs. For King County, the main way that water use is managed is by restrictions on outdoor water use for landscaping. A maximum permissible evapotranspiration is allotted that forces the property owner to reduce the amount of pervious area devoted to turf grass. Stormwater run-on to the pervious area can be used for an extra credit. The amounts of irrigable area for three typical single family lot sizes are shown below.

The advantage of clustering is obvious from inspection of Table 3-5. The amount of irrigable area per house is reduced from 5 , 000 sq. ft. to 1, 500 sq. ft. , a reduction of 70%. This is the main savings in water use. However, from a stormwater runoff point of view, the imperviousness would increase.

Table 3-5 .Typical lot sizes and irrigable area,King County,WA (Sakrison 1996).

Density	Lot Size, (sq.ft.)	Irrigable Area Per lot (sq.ft.)	% of total
Low	10,000	5,000	50
Medium	7,000	3,000	43
High	4,500	1,500	33

Lawn watering has increased in the U.S. as population migration occurs to warmer, more arid areas. Also, urban sprawl means much larger irrigable area per dwelling unit. Lawn watering needs are a dominant component of peak water use in urban areas. Reuse of treated wastewater and stormwater for lawn watering appears to be a very attractive possibility for more sustainable communities.

Infiltration and Inflow

Infiltration and inflow are major issues in urban stormwater management. For example, the results of studies of Boulder, CO indicate that I/I is the major source of flow during high flow periods, which might cause SSOs (Heaney et al. 1996). Indeed, the actual sewage flow in the system is 8-10 mgd whereas flows reach 45- 50 mgd during peak periods as shown in Figure 3-6. Thus, I/I is over four times the amount of legitimate dry weather flow (DWF). For Boulder, evidence exists that the I/I is clean ground water since pollutant concentrations drop as sewage flow increases. Thus, pollutant loads remain relatively constant. I/I is discussed in detail in Chapter 6.

Summary of Sources of Dry-Weather Flow into

Sanitary and Combined Sewers

Based on a sampling of nearly 1, 200 houses in 12 North American cities, in which flows were measured for four weeks in each house, very accurate information is available on indoor water use patterns. Indoor residential water use averages 63. 2 gpcd and remains constant throughout the year. Commercial, industrial, and public uses need to be added to this amount to estimate total water use. Essentially all of the indoor water use enters the sanitary or combined sewers. Outdoor water use is an important, and highly variable, water use.

Outdoor water use exceeds indoor water use on an annual average in more arid parts of the country. It also the primary cause of peak summer water use, and can range as high as five to six times indoor water use during these periods. Because of its seasonal nature, outdoor water use is a major component of the peak design flow as is water for firefighting.

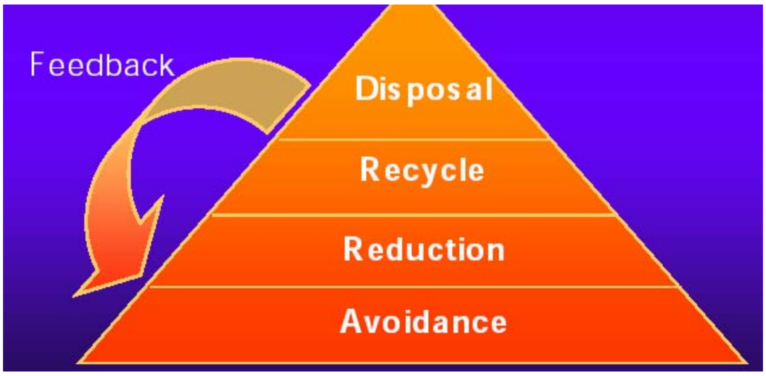
Water conservation practices can reduce water use significantly, particularly outdoor water use. The increasingly high cost of treating water should encourage a new look at dual water systems and more aggressive reuse systems. Infiltration and inflow are the main unknowns in designing sanitary sewer systems. I/I varies widely within a city and across cities. Contemporary practice still allows much higher peak flows to account for this uncertainty.

The primary source of degraded water quality for residential uses is toilet flushing, which accounts for about 30%of the DWF. Faucet water is also of concern, especially where garbage grinders are used. Thus, about 50 %of the DWF could be classified as “black water ”. The remaining sources including showers, baths, clothes washers, and dishwashers would be classified as “grey water ”. The largest source of illicit “wastewater ” is I//I which can range from a small fraction to several times DWF.

The conclusion from this simple water budget is that only a small portion of the wastewater entering sewers requires a high level of treatment. The remaining water could receive less treatment or does not need treatment because it is probably the infiltration of clean groundwater. This mass balance indicates that innovative changes in current practices may be very cost-effective.

Water Management Concept

Water Conservation Hierarchy



Ref: Water Conservation An Urban Planning Perspective, Catherine Fleming, October 2002

Principles developed by the Water Conservation Partnership Project should be reflected in the Planning Strategy and all Development and Natural Resource Management Plans.

1. Avoidance

Encourage where possible development that uses waterless options such as :

• Water free gardens and landscape design ie permeable paving

• Dry composting toilets

• Shading and natural ventilation to cool houses rather than evaporative cooling

2. Reduce

Planning policies should require development to reduce reliance on reticulated water by:

• Water efficient landscaping (xeriscaping)

• Using locally collected water supplies such as rainwater tanks/gutters

• Identifying sites for the location of aquifer storage and recovery schemes

• Installation of water efficient devices

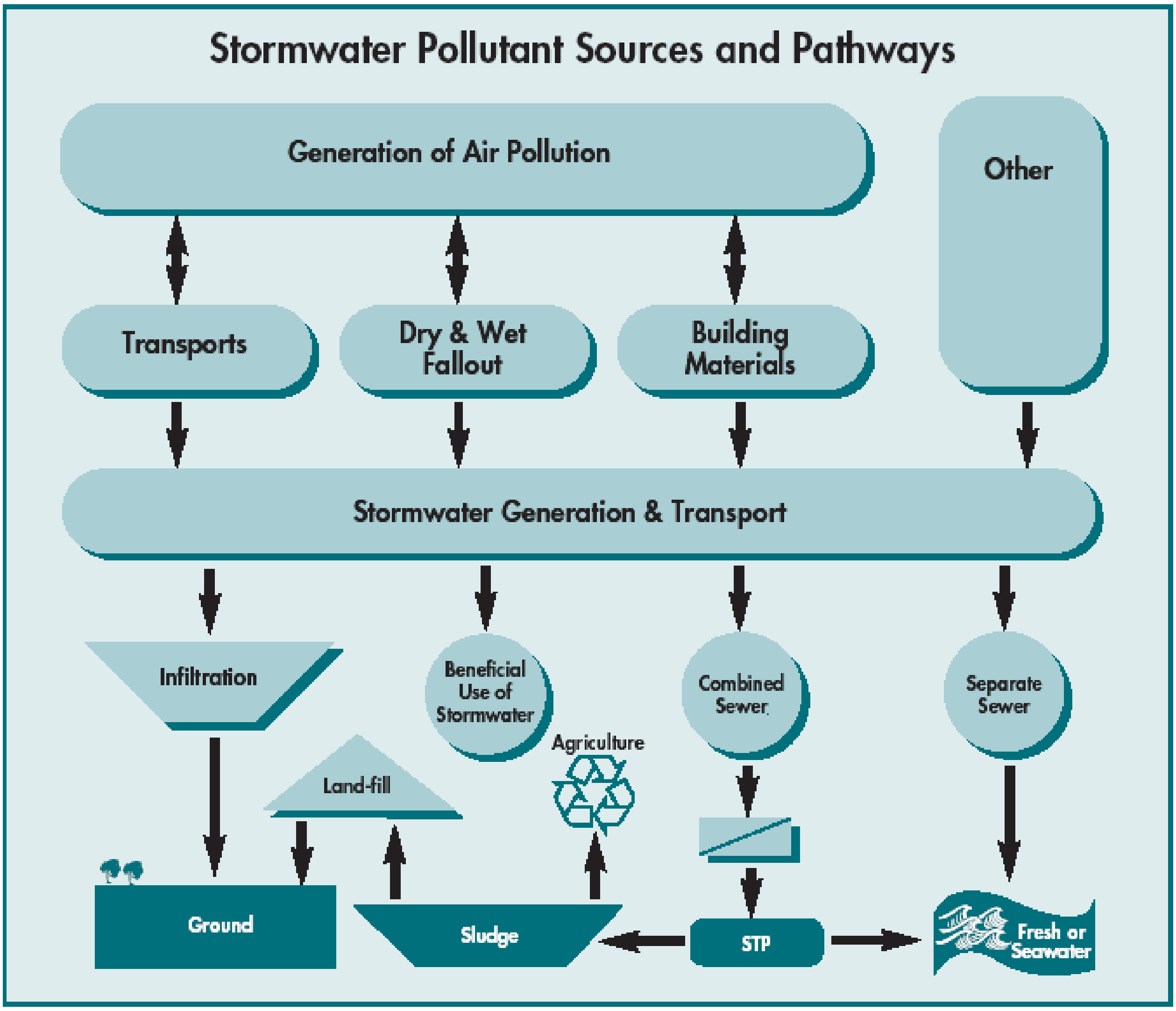
3. Recycle

Planning policies should encourage development to use waste water or reclaimed water by:

• Installation of reuse systems in residential development where health and other requirements are met.

4. Disposal

Development should ensure that the disposal of water or treated wastewater does not cause degradation of the catchment, coastal or marine environments.



Ref: NEWSLETTER OF THE COOPERATIVE RESEARCH CENTRE FOR CATCHMENT HYDROLOGY

Components for scalability

- ***Water demand management***, in order to minimize wasteful use of water, and so reduce the need for new source development and limit the production of wastewater;

- ***Reuse and recycling of water***, in order to minimize the need for wastewater collection, treatment and disposal;

- ***Improved rainwater management***, reducing runoff by on-site or local measures, including detention and treatment, and the reuse of stormwater to benefit the community, such as storage for fire fighting and recreational or amenity use, thus reducing uncontrolled discharge to surface waters;

- ***Nutrient recovery***, whether at the household level (for example, ecological sanitation), or on a wider scale (for example, urban agriculture);

- ***Intermediate technologies***, household and community-level construction, operation and management of facilities, and permit reuse and/or disposal at the local level;

- ***Institutional arrangements and mechanisms*** that stress the involvement of the users, encourage the participation of the local sector, facilitate cooperation across zone or sub-zone boundaries (such as wholesale – retail relationships for service delivery), and ensure the provision of technical assistance across zone boundaries where needed;

- ***Economic analysis*** that illustrates the economic benefits of good planning and solutions as well as the consequences of inappropriate development (for example, in terms of environmental damage; wasteful use of water, energy or other resources; or relying on imported skills and equipment and so failing to make the best use of local resources);

- ***Scalability analysis*** that determines whether problems should be solved within the area of concern itself, or whether a joint solution should be selected to serve more than one area (for example, a zone-wide system). Environmental, social, practical, economic and financial considerations must be analyzed to determine appropriate scaling for each are and usage.

Water demand management

Water consumption in Auroville

Evaluated Water Consumption in Auroville at present

From Evaluation on Auroville Population	2500 m3/d	0.625 m3/d/c
From reavaluted wells data	3500 m3/d	0.875 m3/d/c

Evaluated Water Consumption Repartition in Auroville
(as per Standard classification)

	Consumption lcd
Domestic use	185
Industrial & Commercial use	31
Public use (gardening, park, road, public fontain)	370
Wastes (10%)	59
Field Irrigation	230
Average Municipal consumption	**875**

Water Consumption in Indian Average Town

	Consumption lcd
Domestic use	135
Industrial use	50
Commercial use (factories, offices, hospitals, hostels, restaurants, schools)	20
Public use (gardening, park, road, public fontain)	10
Wastes	55
Average Municipal consumption	**270**

Reducing water consumption: A step by step evaluation

Domestic consumption

Water Consumption in Auroville

	Actual Water Consumption l/d	
Bathing	60	32%
Cleaning of House	10	5%
Cooking	7	4%
Drinking	3	2%
Flushing of Latrine	30	16%
Washing of Clothes	60	32%
Washing of Ustensils	15	8%
Total	**185**	**100 %**

A National Study of Water and Energy Consumption in Multifamily Housing

National Research Centre, Boulder, Colorado, November 2002

This study is an updated version of the March 2001 *A National Study of Laundry-Water Use in Multihousing*, conducted by the National Research Center. The original study compared laundry-water use between 191 in-unit washing machines and 50 common area washing machines in 8 apartment buildings in 4 cities across the U.S.

The study results show that residents with in-apartment laundry machines used more water, and consequently more energy, than those who used common area laundry facilities. In fact, the study revealed that residents of apartments with in-unit washing machines used **3.3 times more water** than residents utilizing common area washing machines. Consequently, the **energy consumption** is about **5 times higher**.

Estimated laundry-water use per apartment unit per week was 860 liters for residents with in-unit washers and 260 liters for residents with common area laundry rooms.

According to the metering information gathered through the study, apartment residents with in-unit washing machines do **5.22 loads** of laundry **per** week per unit, while residents utilizing a common area laundry room do **2.16 loads** of laundry **per unit per week**.

Farming

TABLE 4. Water Loss Under Various Irrigation Methods.

	Temperate Climate	**Hot Climate**
Surface Irrigation	30 - 45%	35 - 50%
Gate pipe Irrigation	15 - 20%	20 - 25%
Sprinkler Irrigation	6 - 9%	10 - 20%

Worldwide Loss of Soil and a Possible Solution

Recently, in 1994, the United States Department of Agriculture reported that approximately 12,000 pounds of soil were being lost per acre per year from wind and water erosion of U.S. land farmed with large-scale techniques. According to soil conservation specialists in Iowa, approximately 16,000 pounds of soil per acre per year were being lost earlier due to wind and water erosion at the time when soil conservation practices were instituted in the 1970's.

Since the average person consumes approximately 2,000 pounds of food annually, the above data can be developed to show that approximately 8 pounds of soil were previously lost due to wind and water erosion for each pound of food eaten. Currently, approximately 6 pounds of soil are being lost due to wind and water erosion per pound of food eaten annually.

In addition, in the late 1970's, the California government issued statistics indicating that in California it was taking *as much as* 2,000 years for nature to build up 1 inch of soil, and that California large-scale agriculture was depleting *as much as* 1 inch of topsoil every 25 years. Normally it takes an average of 500 years for nature to build up 1 inch of topsoil. To grow good crops agriculturally, 6 inches of topsoil are required. Therefore, approximately 3,000 years are needed to build up a reasonable agricultural soil. In contrast, the 12,000 pounds per acre of soil being lost in the U.S. *on the average* annually is 0.0356 inch (approximately 1/28th of an inch) of soil over 1 acre. Since only 1/500th of an inch of topsoil is being built up naturally *on the average* annually in the U.S., soil is being depleted on the average each year approximately 18 times faster than it is being built up in nature.

The Worldwatch Institute reported in its State of the World - 1994 that "Agricultural systems currently have [reached] maximum production and no other systems are in sight to easily increase food production. Decreasing yields are being produced even though increasing amounts of fertilizer are being used." To overcome the coming food crisis, the Asian Vegetable Research and Development Centre has called for a system of agriculture that produces more calories per area with vegetable crops. In Agenda 21, the United Nations calls for "a farming system which is small-scale, low-input, local and organic." The National Research Council-National Academy of Sciences' Board on Agriculture concludes that "new practices are needed in agriculture to protect and more effectively use soil, water and fertilizers and to increase farm productivity."

"Grow Biointensive" sustainable mini-farming meets these goals. It is currently being used in 110 countries, proving its effectiveness for meeting the needs of individuals in a wide range of climates, soils and cultures. With "Grow Biointensive" sustainable mini-farming, a farmer can produce 2 to 6 times the yield compared to commercial agriculture, while using 67%-88% less water, 99% less energy and 50%-100% less purchased organic fertilizer per unit of yield compared with commercial agriculture. It is a method that allows gardeners and farmers to transform scarcity into abundance.

A National Study of Water and Energy Consumption in Multifamily Housing

National Research Centre, Boulder, Colorado

November 2002

Overview:

This study is an updated version of the March 2001 *A National Study of Laundry-Water Use in Multihousing*, conducted by the National Research Center. The original study compared laundry-water use between 191 in-unit washing machines and 50 common area washing machines in 8 apartment buildings in 4 cities across the U.S.

The new study utilizes the original data to estimate energy consumption.

Findings:

The study results show that residents with in-apartment laundry machines used more water, and consequently more energy, than those who used common area laundry facilities. In fact, the study revealed that residents of apartments with in-unit washing machines used **3.3 times more water** than residents utilizing common area washing machines. Consequently, the **energy consumption** is about **5 times higher**.

Estimated laundry-water use per apartment unit per week was 860 liters for residents with in-unit washers and 260 liters for residents with common area laundry rooms.

According to the metering information gathered through the study, apartment residents with in-unit washing machines do **5.22 loads** of laundry **per** week per unit, while residents utilizing a common area laundry room do **2.16 loads** of laundry **per unit per week**.

Wastewater & Reuse

Wastewater : Treat locally !

During the last 10 years, Auroville has carry out a large and rather successful effort in term of domestic-like wastewater management. With the basic understanding of low technology and low power input together with limited maintenance, a range of technical solutions, fitting very well with our conditions and possibilities, have been found and implemented.

The initial stage mainly focused on understanding the very nature of wastewater and how to handle it tropical conditions. A very important step, as most of the information and know-how available was coming from temperate and rich countries, and need therefore a very serious ground-truthing.

The second stage was focused on the identification of the various methods and techniques available and the possibility to adapt them to our ground reality.

The second one after realization of many different systems, was to analyze the pro and count of each approach, and to see how it fit with our reality as well as future development.

Auroville is today somewhere near the end of this stage, and have made a very valuable and largely recognized work, with about 50 working systems of various design and size operating actually.

The carried experience allow us to give some general statement, and show also the way further investigations and improvement.

We can define the evolution of the thinking and resulting system in that matter as follow:

- ⇒ To solve the problem of hygiene, disturbances and potential public health hazard without external power.
- ⇒ To allow safe recycling of treated water
- ⇒ To allow easy to handle operation and maintenance
- ⇒ To reduce the space requirement and site disturbance generated
- ⇒ To allow scalability by means of decentralized and modular setups
- ⇒ To develop affordable systems.

Today, Auroville is developing decentralized systems for up to 1,000 equivalent capita (ec).

The space requirement is below one square meter per capita for the entire system and cost about **6,000Rs per ec**, or about **3 to 5%** of a residence's cost today.

The most important part of the proposed systems is underground and therefore create no visual disturbance, while the other part are easy to integrate as landscaping part due to there very nature and small size.

Experiments with very promising technologies like EM are ongoing to reduce even further the size of the system and allow further safety on the health hazard side.

In that context, we can consider that the best solution for most of the case in Auroville is to go for decentralized systems at cluster level, and to reuse required water at local level too.

If properly conceived, such an approach is cutting drastically the related infrastructure while allowing maximum flexibility in regard of the unknown population growth factor.

About centralized treatment facilities

They have very serious drawback:

- High investment, energy, operating and maintenance costs
- Sewers are very costly and suffer of fast degradation under tropical conditions.
- The scalability is often difficult.

Reuse of Rainwater: High quality water available !

According to CSE, you can harvest for 100m2 of roof :

1. You can harvest **79840 litres** of water annually.
2. This quantity is adequate to meet the drinking water demands of a family of 4 for **1996 days.**
3. 3. Suggestion For Pondicherry : **Storage and recharge of ground aquifers**

In many articles over the topic to water today however headings are noticeable how: "each drop counts" or "drinking water in danger".

In the last decade the borders of the central potable water supply structures showed up even in water-rich countries as in Germany, the Netherlands, Austria and Switzerland. The most noticeable effects are rising drinking and waste water prices.

Advantages of the rain water use:

- possible reduction of detergent consumption over 50 %
- no calcifying the washing machine, no additives necessarily for the lime reduction
- the ion-poor rain water reduces the occurrence of urine stone at WC's
- the soft rain water offers an optimal irrigation medium for plants
- Saving of expensive water and wastewater fees

Optimal water quality

Investigations show the good water quality of the rain water plants, which is sufficient for the requirements for WC flushing, garden irrigation and laundry washing in the best way.

ENVIRONMENTAL ADVANTAGES

Collecting the rain that falls on a building to be used nearby is a simple concept.

Since the rain harvested is independent of any centralized system, it is promoting self-sufficiency and helping to foster an appreciation for this essential and precious resource.

Collecting rainwater is not only water conserving, it is also energy conserving since the energy input required to operate a centralized water system designed to treat and pump water over a vast service area is bypassed. Rainwater harvesting also lessens local erosion and flooding caused by runoff from impervious cover such as pavement and roofs, as some rain is instead captured and stored. Thus, stormwater run-off, the normal consequence of rainfall, which picks up contaminants and degrades waterways, becomes captured rainfall which can then fulfill a number of productive uses.

Policymakers may wish to reconsider present assumptions regarding impervious cover and consequent run-off management strategies.

QUALITATIVE ADVANTAGES

A compelling advantage of rainwater over other water sources is that it is one of the purest sources of water available. Indeed, the quality of rainwater is an overriding incentive for people to choose rainwater as their primary water source, or for specific uses such as watering houseplants and gardens.

Rainwater quality often exceeds that of ground or surface waters: it does not come into contact with soil and rocks where it dissolves salts and minerals, and it is not subject to many of the pollutants that often are discharged into surface waters such as rivers, and which can contaminate groundwater. However, rainwater quality can be influenced by where it falls, since localized industrial emissions affect its purity. Thus, rainwater falling in non-industrialized areas can be superior to that in cities dominated by heavy industry, or in agricultural regions where crop dusting is prevalent.

Rainwater is soft and can significantly reduce the quantity of detergents and soaps needed for cleaning, as compared to typical municipal tap water. Additionally, soap scum and hardness deposits disappear, and the sometime required water softener is eliminated. Water heaters and pipes will be free of deposits caused by hard water and should last longer.

Rainwater's purity also makes it an attractive water source for certain industries for which pure water is a requirement.

And the Future?

Ecological sanitation

By looking to the repartition of domestic wastewater generation, you can realize that berween 16 and 25% is coming from the toilets. The water is used in toilets mainly for transport purpose. If toilet waste is mixed with a lot of water, the large volume turns to a potentially dangerous flow of waste that has to be treated at high costs, because most of the hygienic danger and nutrients are coming from faecal matters . At the same time this mixing makes simple treatment and higher quality reuse impossible because of faecal contamination and excess of nutrients.

One person produces about 500 litres of urine and 50 litres of faeces per year. Today in Auroville, the same person, having access to tap water, produces about 66,000 litres of wastewater per year. If the toilets water would be collected separately with low dilution it can be converted to safe natural fertiliser, preventing spreadout of pathogens and water pollution too.

Due to the very different characteristics of blackwater (from the toilets) and greywater (household wastewater without blackwater) new sanitation concepts will produce fertiliser from blackwater and give a good opportunity for reuse of treated greywater. Blackwater has a composition where most of the organic matter and particulate nutrients are in the solids.

In contrast, the (urine) contains nearly all of the valuable soluble nutrients as N, P, K and others.

This new development required a lot of investigation before to come mature. But we can right a way underline some of the benefit of such an approach.

- Reduction of water consumption (up to 25%)
- Easy to handle and safe by-product
- Highly hygienic and valuable by-product.
- Cutoff on treatment facilities and related infrastructure

While being in primary stages this very promising new approach, called ecological sanitation, is under investigation all over the world.

Further that what is discussed her, the general attend is to limit the negative impact of human activities on environment, not only be reducing the demand and the pollution generated, but also by reintegrating the valuable waste in land production. A human being produces exactly the amount of nutrients that is needed for growing his or her food (measured in crops) – 7.5 kg of nitrate, phosphorus and potassium for 250 kg of crops. Why not to benefit of it?

Ultrasound washing

Another promising technology is the use of ultrasound for the sake of cleaning clothes and dishes. The main advantage resides in the absence of detergents in the process. Detergents , very harmful to the environment, are difficult to treat and generate over cost.

Ultrasound washing process does not required hot water, which represent a very important saving of energy. Finally, Russian experiments seem to indicate that it is possible to achieve the same result with minimum water.

This technology is already available on the market and is under continuous investigation.

Wastewater management

There are 3 ways to think a bout wastewater management.

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.

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 core difficulty of wastewater management is not the solid part, it is the polluted water.

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.

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

NH_3 mg/L	--	67.1	38.7	36.8	--	--	51.9	25.2	27.5	23
PO_4 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.

Storm Water Management

A Changing Practice in Stormwater

Stormwater management for the protection of receiving waters

⇒ stormwater drainage
⇒ stormwater as a resource
⇒ protection of receiving water quality
⇒ protection of downstream aquatic habitats

Development & Water Conservation

• Urbanisation increases runoff from impervious surfaces , causing s tormwater flooding and non-point source pollution problems

• Water sensitive urban design promotes the retention of stormwater on-site to maximise infiltration

Stormwater Quality Improvement & Water Sensitive Urban Design

Creation/integration of stormwater management elements into urban design and landscape amenities.

Ref: Cooperative Research Centre for Catchment hydrology, Monsah University

Development of City Changes Land and Runoff

When land is developed, the hydrology, or the natural cycle of water is disrupted and altered.

Clearing removes the vegetation that intercepts, slows and returns rainfall to the air through evaporation and transpiration. Grading flattens hilly terrain and fills in natural depressions that slow and provide temporary storage for rainfall. The topsoil and sponge-like layers of humus are scraped and removed and the remaining subsoil is compacted. Rainfall that once seeped into the ground now runs off the surface. The addition of buildings, roadways, parking lots and other impervious surfaces further reduces infiltration and increases runoff.

Depending on the magnitude of changes to the land surface, the total runoff volume can increase dramatically. These changes not only increase the total volume of runoff, but also accelerate the rate at which runoff flows across the land. This effect is further exacerbated by drainage systems such as gutters, storm sewers and lined channels that are designed to quickly carry runoff to rivers and streams.

Development and impervious surfaces also reduce the amount of water that infiltrates into the soil and groundwater, thus reducing the amount of water that can recharge aquifers and feed streamflow during periods of dry weather.

Finally, development and urbanization affect not only the quantity of stormwater runoff, but also its quality. Development increases both the concentration and types of pollutants carried by runoff. As it runs over rooftops and lawns, parking lots and industrial sites, stormwater picks up and transports a variety of contaminants and pollutants to downstream waterbodies. The loss of the original topsoil and vegetation removes a valuable filtering mechanism for stormwater runoff.

The cumulative impact of development and urban activities, and the resultant changes to both stormwater quantity and quality in the entire land area that drains to a stream, river, lake or estuary determines the conditions of the waterbody. Urban development within a watershed has a number of direct impacts on downstream waters and waterways.

These impacts include:

- Changes to stream flow
- Changes to stream geometry
- Degradation of aquatic habitat
- Water quality impacts

Summary of Urban Stormwater Pollutants

Constituents	Effects
Sediments - Suspended Solids, Dissolved Solids, Turbidity	• Stream turbidity • Habitat changes • Recreation/aesthetic loss • Contaminant transport • Filling of lakes and reservoirs
Nutrients - Nitrate, Nitrite, Ammonia, Organic Nitrogen, Phosphate, Total Phosphorus	• lgae blooms • Eutrophication • Ammonia and nitrate toxicity • Recreation/aesthetic loss
Microbes - Total and Fecal Coliforms, Fecal Streptococci, Viruses, E.Coli, Enterocci	• Ear/Intestinal infections • Shellfish bed closure • Recreation/aesthetic loss
Organic Matter - Vegetation, Sewage, Other Oxygen Demanding Materials	• Dissolved oxygen depletion • Odors • Fish kills
Toxic Pollutants - Heavy Metals (cadmium, copper, lead, zinc), Organics, Hydrocarbons, Pesticides/Herbicides	• Human & aquatic toxicity • Bioaccumulation in the food chain
Thermal Pollution	• Dissolved oxygen depletion • Habitat changes
Trash and debris	• Recreation/aesthetic loss

Addressing Stormwater Impacts

How to effectively deal with the impacts of urban stormwater runoff through effective and comprehensive stormwater management.

Stormwater management involves both the prevention and mitigation of stormwater runoff quantity and quality impacts through a variety of methods and mechanisms.

- Using the most current and effective erosion and sedimentation control practices during the construction phase of development
- Controlling stormwater runoff peaks, volumes and velocities to prevent both downstream flooding and streambank channel erosion
- Treating post-construction stormwater runoff before it is discharged to a waterway
- Implementing pollution prevention practices to prevent stormwater from becoming contaminated in the first place
- Using various techniques to maintain groundwater recharge

Stormwater Better Site Design

The first step in addressing stormwater management begins with the site planning and design process. Development projects can be designed to reduce their impact on watersheds when careful efforts are made to conserve natural areas, reduce impervious cover and better integrate stormwater treatment. By implementing a combination of these nonstructural approaches known as stormwater better site design practices, it is possible to reduce the amount of runoff and pollutants that are generated from a site and provide for some nonstructural on-site treatment and control of runoff. The goals of better site design include:

- Managing stormwater (quantity and quality) as close to the point of origin as possible and minimizing collection and conveyance
- Preventing stormwater impacts rather than mitigating them
- Utilizing simple, nonstructural methods for stormwater management that are lower cost and lower maintenance than structural controls
- Creating a multifunctional landscape
- Using hydrology as a framework for site design

Better site design for stormwater management includes a number of site design techniques such as preserving and developing natural features and resources, effectively laying out the site elements to reduce impact, reducing the amount of impervious surfaces, and utilizing natural features on the site for stormwater management. The aim is to reduce the environmental impact "footprint" of the site while retaining and enhancing the owner/developer's purpose and vision for the site. It can reduce the cost of infrastructure while maintaining or even increasing the value of the property.

Reduction of adverse stormwater runoff impacts through the use of better site design should be the first consideration of the design engineer. Operationally, economically, and aesthetically, the use of better site design practices offers significant benefits over treating and controlling runoff downstream. Therefore, all opportunities for using these methods should be explored and all options exhausted before considering structural stormwater controls.

The reduction in runoff and pollutants can reduce the required runoff peak and volumes that need to be conveyed and controlled on a site and, therefore, the size and cost of necessary drainage infrastructure and structural stormwater controls. In some cases, it may eliminate the need for structural controls entirely. Hence, better site design concepts can be viewed as both a water quantity and water quality management tool.

The use of stormwater better site design can also have a number of other ancillary benefits including:

- Reduced construction costs
- Increased property values
- More open space for recreation
- More pedestrian friendly neighborhoods
- Protection of sensitive forests, wetlands and habitats
- More aesthetically pleasing and naturally attractive landscape
- Easier compliance with wetland and other resource protection regulations

List of Stormwater Better Site Design Practices and Techniques

- **Conservation of Natural Features and Resources**
  - ⇒ Preserve Undisturbed Natural Areas
  - ⇒ Preserve Riparian Buffers
  - ⇒ Avoid Floodplains
  - ⇒ Avoid Steep Slopes
  - ⇒ Minimize Siting on Porous or Erodible Soils
- **Lower Impact Site Design Techniques**
  - ⇒ Fit Design to the Terrain
  - ⇒ Locate Development in Less Sensitive Areas
  - ⇒ Reduce Limits of Clearing and Grading
  - ⇒ Utilize Open Space Development
  - ⇒ Consider Creative Development Design
- **Reduction of Impervious Cover**
  - ⇒ Reduce Roadway Lengths and Widths
  - ⇒ Reduce Building Footprints
  - ⇒ Reduce the Parking Footprint
  - ⇒ Reduce Setbacks and Frontages
  - ⇒ Use Fewer or Alternative Cul-de-Sacs
  - ⇒ Create Parking Lot Stormwater "Islands"
- **Utilization of Natural Features for Stormwater Management**
  - ⇒ Use Buffers and Undisturbed Areas

⇒ Use Natural Drainage ways Instead of Storm Sewers
⇒ Use Vegetated Swale Instead of Curb and Gutter
⇒ Drain Rooftop Runoff to Pervious Areas

Site design should be done in unison with the design and layout of stormwater infrastructure in attaining stormwater management goals.

Stormwater Better Site Design Process

The first step involves identifying significant natural features and resources on a site such as forest areas, stream buffers and steep slopes that should be preserved to retain some of the original hydrologic function of the site.

Next, the site layout is designed such that these conservation areas are preserved and the impact of the development is minimized. A number of techniques can then be used to reduce the overall imperviousness of the development site.

Finally, natural features and conservation areas can be utilized to serve stormwater quantity and quality management purposes.

Identify Natural Features and Resources – Delineate Site Conservation Areas
Design Site Layout to Preserve Conservation Areas and Minimize Stormwater Impacts
Use Various Techniques to Reduce Impervious Cover in the Site Design
Utilize Natural Features and Conservation Areas to Manage Stormwater Quantity and Quality

Urban distribution concept

General Layout

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, as well as in concentric rings following the crown roads.

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.

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.

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.

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).

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.

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,…).

Groundwater and Hydrology

A basic understanding of groundwater and surface water

The ultimate source of water in Auroville's area is rain, as everywhere else in the world. This affirmation is even truer here because of the absence of perennial river and because of the highly depleted groundwater.

Auroville is sitting on a multiple aquifer system. In fact, 8 different aquifers are present under the most important part of Auroville, each one with its own water quality, storage capacity, permeability etc. Moreover, these aquifers are more or less interconnected, both due to their natural structure and to human intervention (bore wells).

While several studies have been conducted on Auroville area's groundwater, the specificity of such a complex system in coastal area is not well known. The most critical part : the interaction with sea water, is only very roughly evaluated, and the very last study conducted in Auroville area shows very surprisingly that the actual cause of contamination of one of our most promising aquifer is not due to sea water intrusion yet.

On the opposite, what is well known is that the actual extraction rate is largely exceeding the recharge in most of the area. The recharge itself is anyhow bring down because of the general degradation of the traditional storage structures, interconnection channels, drainages, as well as bad soil conservation practices and irrigation. The most efficient and cheap way to recharge the aquifer is by the traditional tank irrigation practice now often replaced by groundwater irrigation.

The tendency is clearly toward further degradation both in quality and in quantity: further wells development, over extraction, pollution through fertilizers and pesticides as well as chemicals from various industrial sites are the various strains following on the ecosystem and more precisely the groundwater. Even with drastic and rapid changes in human behavior, the fundamental sources of all these diseases, and hoping total reversibility is still possible, it will take time to come back to a healthy situation.

In that perspective, the area of concern can not at any rate be limited to Auroville: the groundwater exploited in Auroville is globally the same that the one used in the surrounding villages and lands and therefore is very much affected by the general degradation and bad practices. To alleviate and sustain Auroville's groundwater resources can only be done by looking at and enhance a broader area.

It is therefore of primary importance to understand the level of interaction of such a complex system and to come with an appropriate management of the resources without dispossessing the other users but helping them and encouraging them in the same way. Auroville has been created to do researches and to disseminate the results of these researches. The neighborhood should be the first beneficiary of such a positive demarche.

Geological Set-Up & Hydrogeological Condition in Auroville and its bioregion

The ground water investigation carried out in Auroville 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 program and design suitable structures for domestic and irrigation purposes.

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 villages of the Kaluvelly watershed showed excessive extraction of ground water and seawater intrusion in some of the coastal villages. High salinity is also seen in many of the interior villages of the watershed and the trend of development is very alarming.

Considering the fast depletion of the groundwater, the possibilities of seawater intrusion is very likely and if left unattended would endanger the entire south part of Kaluvelly watershed, and therefore Auroville. It must be clear that remediation of seawater intrusion cannot be achieve during a human life.

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.

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.

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.

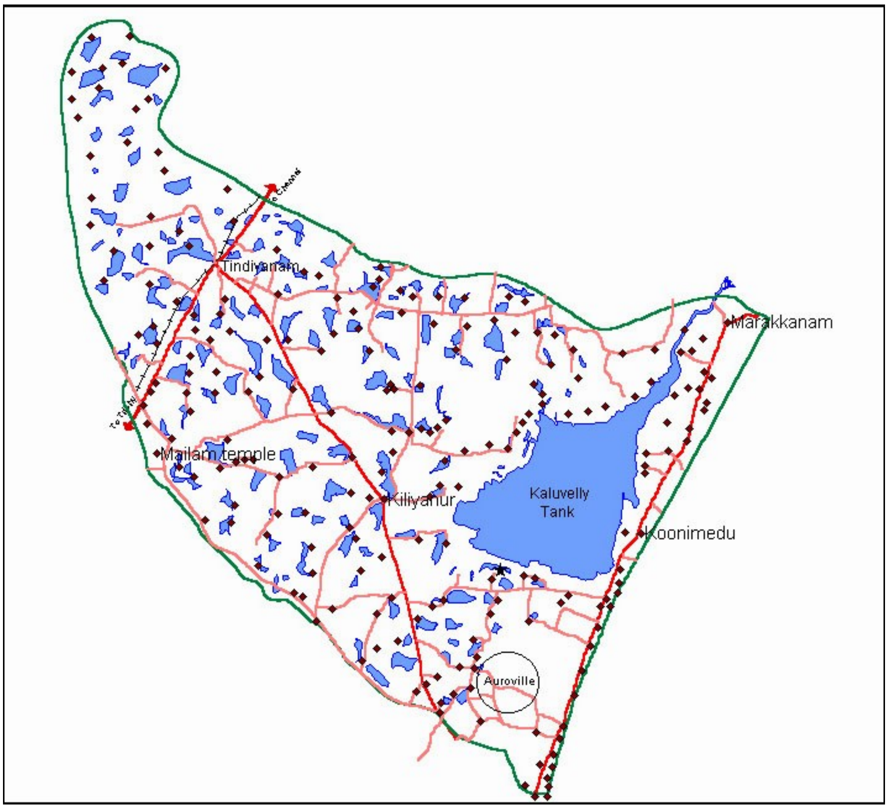
Along the high ground, short flow courses of well-formed gullies and drainage towards west (topo-low) are observed. Similarly a few streamlets do occur in the eastern slopes of the Auroville drainage towards the sea.

The shallow Kaluvelly swamp located to the North of Auroville has an area extent of 72 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 one of definition of the Auroville bioregion, even if other parameters can enlarge it to a larger or different extend.

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.



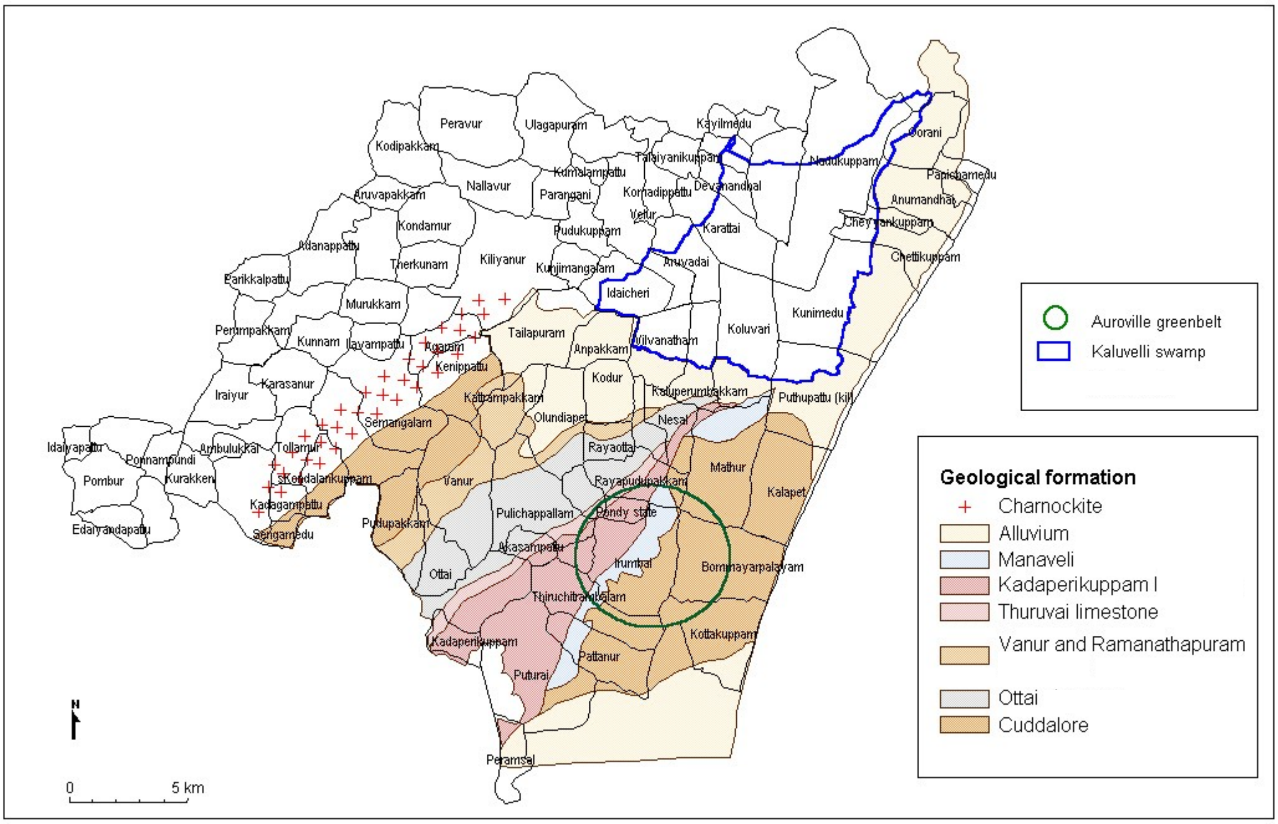
Kaluvelli Watershed or Bioregion

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



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.

HYDROGEOLOGY - Occurrences of ground water

A concise description of the main aquifers of concern in Auroville could be useful at this stage. To start with, the definition of a few terms, essential to get a good comprehension of the subject.

AQUIFER : A geological formation (or more than one) that is porous enough and permeable enough to transmits water at a rate sufficient to feed a spring or a well. An aquifer transmiit more water than an aquitard.

AQUITARD : A part of a geological formation (or one or more) that is of much lower permeability than an aquifer and will not transmit water at a rate sufficient to feed a sprinf or for economic extraction by a well.

AQUICLUDE : An impermeable layer of rock that does not allow water to move through it.

PERMEABILITY : Ability of a material to transmit fluids (water) through itspores when subjected to pressure or difference in head. Description of the ease with which a fluid may move through a porous medium.

TRANSMISSIVITY : Flow capacity of an aquifer. Equal to the product of hydraulic conductivity times the saturated thickness of the aquifer.

HYDRAULIC CONDUCTIVITY : A property of porous medium and the fluid (water) content of the medium.

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. The crystalline basement underlies Auroville area.

The discontinuous aquifer of Charnokites

It presents a high salinity (3200 µS/cm), and is therefore not of interest for further use.

Ramanathapuram aquifer

This formation, confined, is usually not used because of high salinity of natural origin, mainly high sulphate content. However, it must be noticed that several wells in Auroville are reaching this aquifer and may get contaminated. It is the case in Aurogreen, Transition and Matrimandir.

This aquifer and Vanur formation are generally considered as one system. Nevertheless, a thin layer of calcareous clay is intercalated between them.

Vanur sandstone aquifer

The lowest usable aquifer, Vanur sandstone, was the least altered of the area's aquifers. However, Vanur sandstone water electrical conductivity increased since some years and its water level decrease drastically. 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. In the Vanur aquifer, some samples show a rapid increase of sulphate.

This particular formation is the most exploited one around Auroville for agricultural purpose. At first evaluation the extraction rate is 20 times higher that the recharge, and therefore the various observed problems.

Because of its very nature and its position in the multiple aquifers system, the ongoing depletion and salination can affect the entire system. According to available data and first calculation, the results show a marine intrusion should have been recorded in the more depressed area (Nathalie GASSAMA, Sophie VIOLETTE, Noémi d'OZOUVILLE, Aline DIA, Nathalie JENDRZEJEWSKI - 2003).

Because of good hydrodynamic properties (transmissivity between 800m2 and 250m2 in 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 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.

Origin of the Salinity and Water Circulation

The Kaluvelly watershed, Origin of the Salinity and Water Circulation, Part one: Geochemical Results and first hydrodynamic calculation - Nathalie GASSAMA, Sophie VIOLETTE, Noémi d'OZOUVILLE, Aline DIA, Nathalie JENDRZEJEWSKI – 2003.

The salinity of a water corresponds to the concentration of total dissolved ions, the electric charge carriers. The increase in salinity, i. e. in total dissolved ions, is a normal way water chemistry evolved during the water-rock interaction increase. When the increase of ionic content is rapid, one can suspect a change in the hydraulic circulation. The easiest way to quantify the salinity is to measure the electric conductivity of water. At a global scale, conductivity ranges from about 10 (rain water) to 60,000 (sea water) µS/cm.

In Auroville and its vicinity, the electric conductivity measured during the study ranges as follows: 100 to 500 µS/cm in the Cuddalore, 600 to 1,800 µS/cm in the Vanur, 500 to 2,200 µS/cm in the charnockites, for the other aquifers from 300 to a maximum of 6,800 µS/cm in the Ottai claystone.

Salinization origins

The different origin of water "salinization" (increase of mineralization) can be ascribed to as follows:

(i) mixing with sea water (direct input at present day or inherited, or through the swamp);

(ii) infiltration of waters concentrated by evaporation;

(iii) mixing with long residence-time waters (high ionic strength waters which circulate for a long time in a crystalline rock body) caused/enhanced by head differences due to the pumping.

To distinguish between these different possibilities, the time evolution of electrical conductivity in aquifers, the impact of evaporation on water chemistry, the simple mixing between surface and sea water, and the mixing with mineralized waters is studied.

Conclusion about salinization

- A slight input of sea water from the swamp is detected in the northern part.
- The evaporation has a non negligible impact.
- Our results, focus on the Vanur sandstone aquifer, show that the main process involved is a mixture with deep waters (sulphate-rich) due to an upward leakage in

the more depressed area (piezometric depression). These sulphate-rich waters can have several origins. They might be issued from the below aquifer, the Ramanathapuram sandstone aquifer which comprises lignite layers.

At present, there is no marine intrusion at the scale of the aquifer.

Ottai clay stone formation

Ottai clay stone formation is outcropping in relatively 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

The Ottai clay is considered as an aquitard and is considered as being recharged mainly from above and underneath aquifers. Anyhow, due to large irregularity in its structure, relatively large pockets of sandy material may be found, allowing good yielding at some places. The hydraulic barrier effect of the Ottai formation is not assessed.

Kadaperikuppam formation

It 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, the 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 μS/cm near Kaluvelly swamps.

This aquifer, is outcropping in a large part of Auroville, mainly in the paddy lands present West of Auroville plateau, where its offer a good scope for iirgation.This aquifer is largely exploited in Auroville it self, while its yielding capacity fluctuate a lot form place to place, but is generally poor.

Thuruvai formation

This aquifer is used for irrigation in the paddy land West side of Auroville plateau.

Manaveli formation

The Cuddalore sandstone aquifer

Cuddalore and Kadapperikuppam aquifers: a pair of piezometers a-e installed at the slopes of eastern uplands (at K.V.K) tapping Cuddalore and Kadapperikuppam aquifers. In between these two aquifers one more aquifer called Manaveli (relatively thinner) also exists.

It can be seen that the potentiometric surface of both the wells show equal response to the recharge and discharge. Thus, despite the geological variation in strata these two aquifers seem to have very good communication with each other.

"STUDY OF GROUNDWATER RESOURCES OF PONDICHERRY AND ITS ENVIRONS"
B.S. Sukhija, D.V. Reddy & I. Vasanthakumar Reddy - National Geophysical Research InstituteHYDERABAD – 500 007 JUNE 1987 Ref:

Transmissivity rate in Cuddalore sandstone is 77m²/day (Danida 1999).

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 was going 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 m²/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 considered the most potential aquifer for the groundwater development in the enlarged area.

The aquifers of alluvium and sands

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

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.

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 hydrohemistry and environmental tritium studies.

Subject	Status
Definition of the concerned groundwater extend	Should be clear by end of the ongoing water resources study
Weather data from multiple weather station needs to be collected and processed	done
To enhance hydro-geological studies, tests need to be carried out to understand not only the horizontal and vertical transmissivity, but also of the respective aquifers. The intermediate aquifers must be investigated.	The second phase of the ongoing groundwater study should allow this specific exploration.
Investigations and monitoring are required near the coastal line to understand the interface see water / groundwater and therefore the risk of see water intrusion	The second phase of the ongoing groundwater study should allow this specific exploration.
Development of an hydrologic model of the area	Ongoing data collection and ground-truthing
Monitoring of piezometric level and salinity needs to be maintain on a routine base	Done but not available for intermediate aquifers (no observation wells)
Survey, integration and update of wells data from Auroville and surrounding area must be conducted.	On going on about 70 surrounding villages on 500skm.
Soil study is required to find the structure and texture of different type soils	Soil map processed. Further investigation needed.
Infiltration and runoff study is required to define the recharge potential	First part on going, second part will start with the second phase of the water study
To improve the groundwater monitoring system, additional observation wells need to be drilled in various	Various funding possibilities to investigate
Topo data	Should be updated soon. It is not possible yet to access to existing good resolution maps
Satellite image	One set available only. Processing ongoing. Investigations ongoing to get other sets

Proposition de nouvelles pistes de recherche

- La mise en place d'un modèle hydrologique
- Approfondir les moyens d 'incitation à une gestion raisonnée de l 'eau
- Développer des moyens de revalorisation du système traditionnel d 'irrigation

In Auroville area, we can find usually 8 of these formation, each one acting as an aquifer. This create a very complex and not well known system, with many level of interferences.

Conclusion and prospects

The geochemical study gives main issues on water salinity origin:

- evaporation,
- input of brackish waters from the swamp in the northern part,
- upward leakage of sulphate-rich waters in the more depressed area.

The hydrodynamic modelling gives some hypotheses on water circulation which need to be constrained by better data set (geological and hydrodynamic). Needs are as follows.

(i) hydrodynamic monitoring of a watershed along at least one hydrologic year

acquisition of water budget parameters (Rainfall, Evapotranspiration, Runoff & Infiltration)

(ii) monitoring of piezometers network of the main aquifers

(iii) pumping tests

acquisition of hydrodynamic parameters (T, K, S)

(iv) interpretation of satellite imagery

acquisition of morpho-physical parameters and their evolution along time (morphology, land cover…).

In order to build a hydrodynamic modelling of the multilayer aquifer system constraint by geochemical and isotopic tracers, taking into account the fresh water-salt water intrusion motion. This modelling should give estimation of water resource quantity and quality evolution at a long time scale.

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).

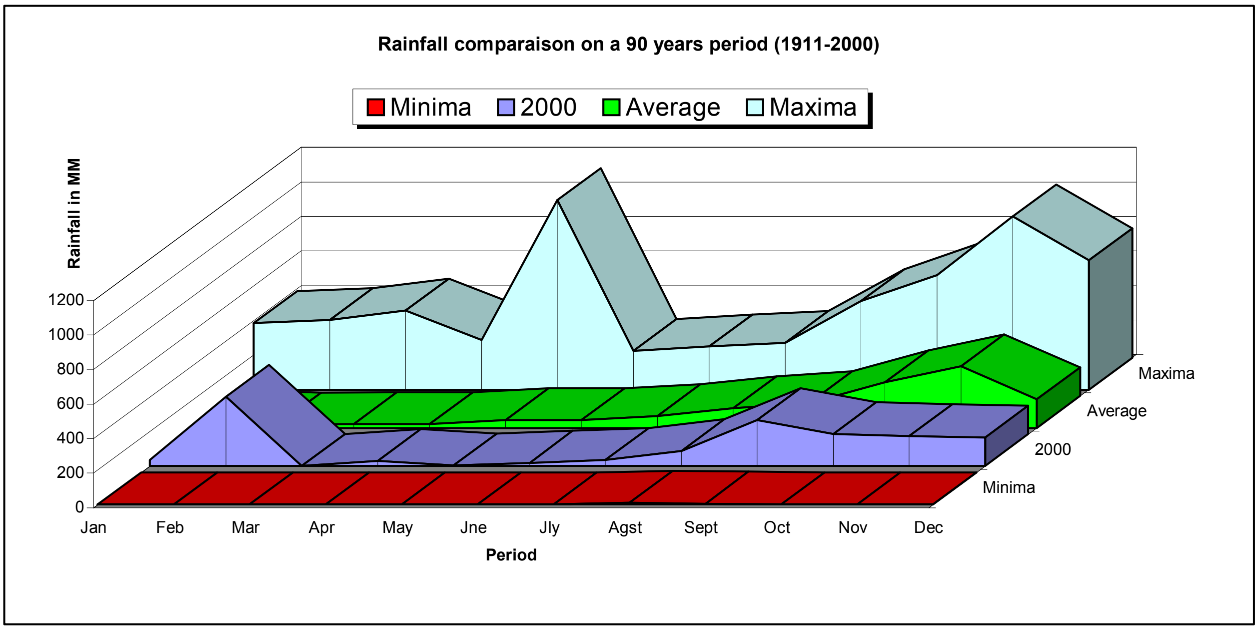
Because of the washing and erosion effects of the rain, the actual programs of erosion

	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

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.

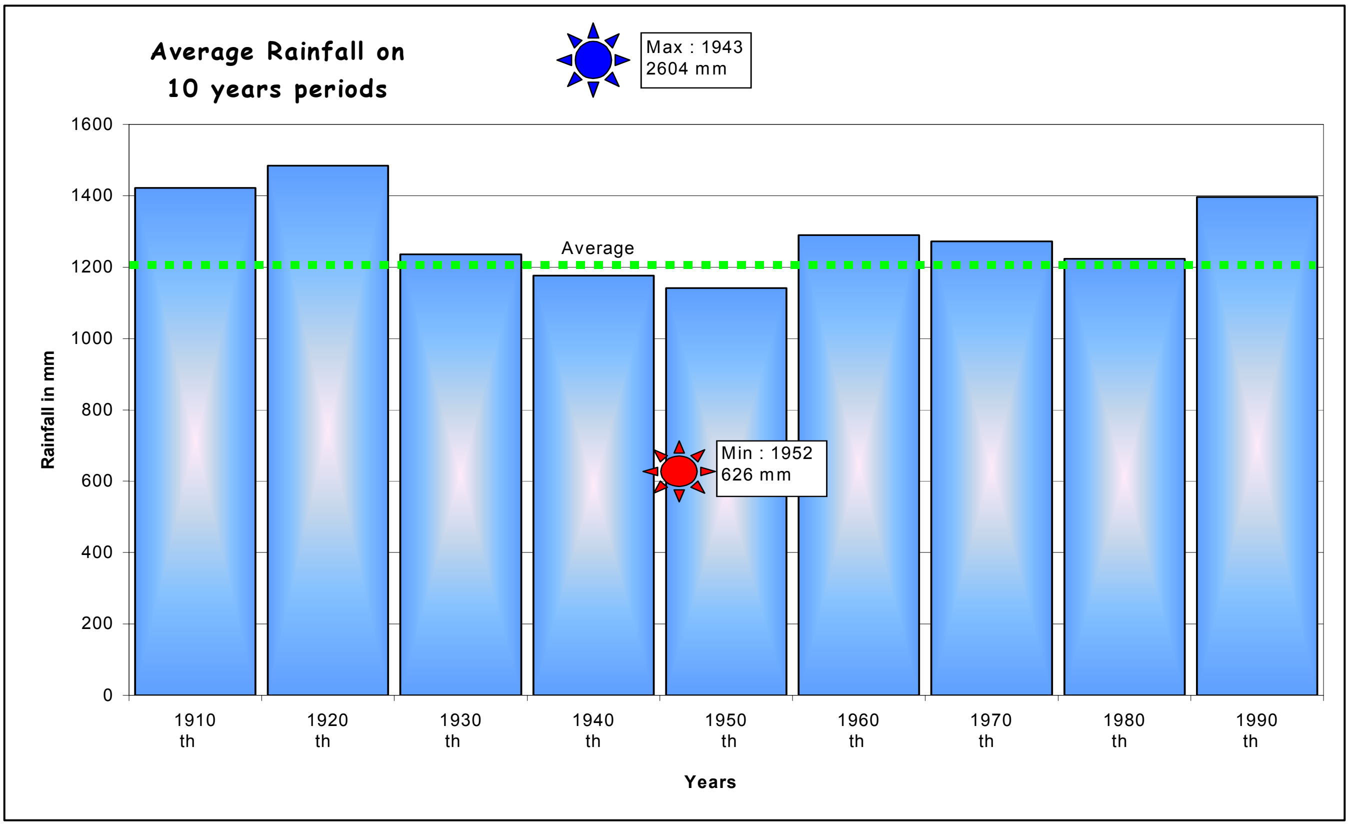
It is equally observed that for a comparable rainfall quantity, the intensity plays a major role on the water table recharge. A time sprayed rainfall will have much better impact on the



Rainfall comparaison on a 90 years period (1911-2000) 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.

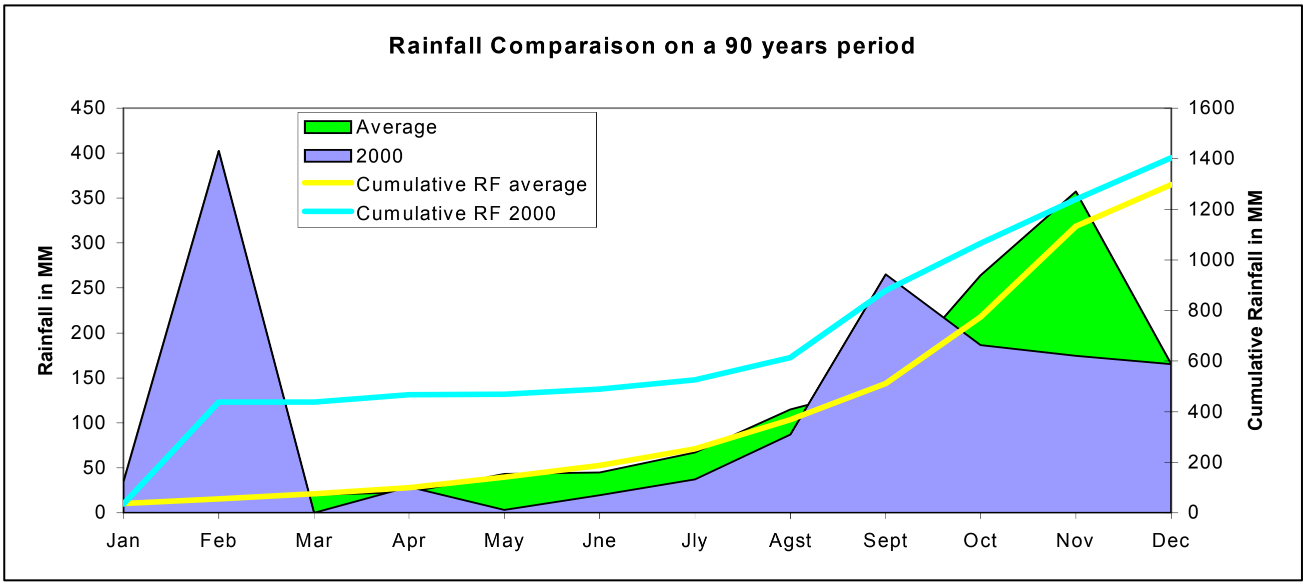
If the average rainfall is 1293mm on a 90 years period (data coming mainly from Pondicherry weather station) 1943 is known for an amazing 2604mm yearly rainfall (in Pondicherry), mainly because of a cyclone during May of this year (maybe the one mentioned by Mother when Sri Aurobindo's room was absolutely 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



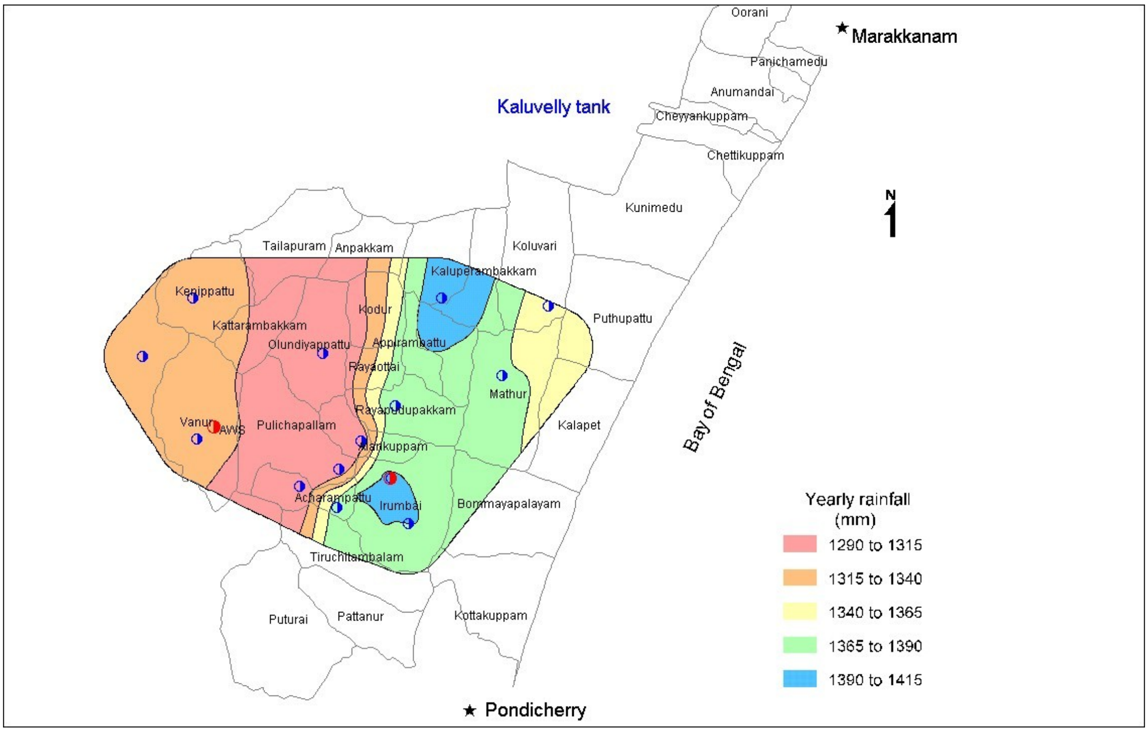
area, because the weather situation in tropical belt is considered as very stable and slow to react. There are controversies within Indian specialist obout potential effect on this area, some considering only temperate latitude as being concerned by such alterations. However, the lasts year rainfalls 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.

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)

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:

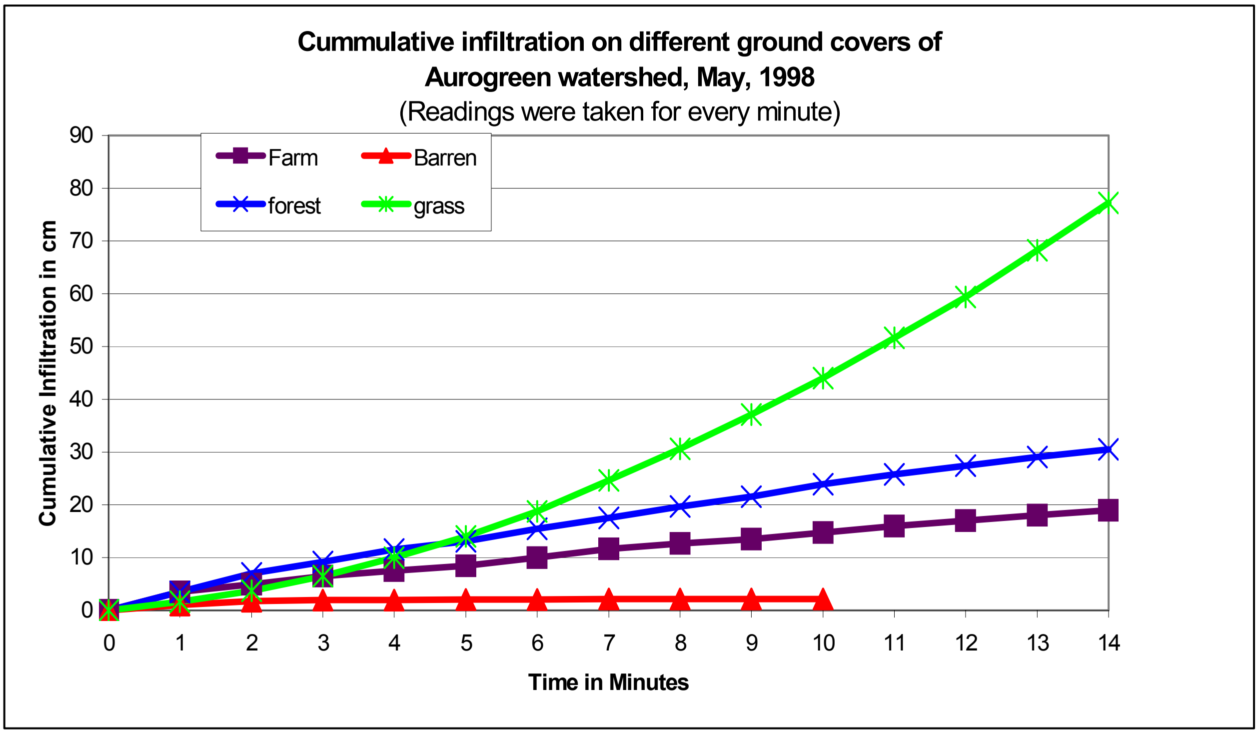
- To reduce the lost per evaporation and evapo-transpiration
- To limit the runoff as much that possible
- Facilitate the infiltration

2. 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



To limit the runoff as much that possible

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.

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.

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.

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		202
Domestic	25	5%	33	5%	40	5%	48	5%	52
Industry	15	3%	45	6%	75	9%	105	11%	120
Energy	19	3%	34	5%	49	6%	64	6%	71
Irrigation	460	83%	549	79%	637	76%	726	74%	770
Others	33	6%	34	5%	35	4%	36	4%	37
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.

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/ capital/ 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.

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.

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.

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.

3. 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.

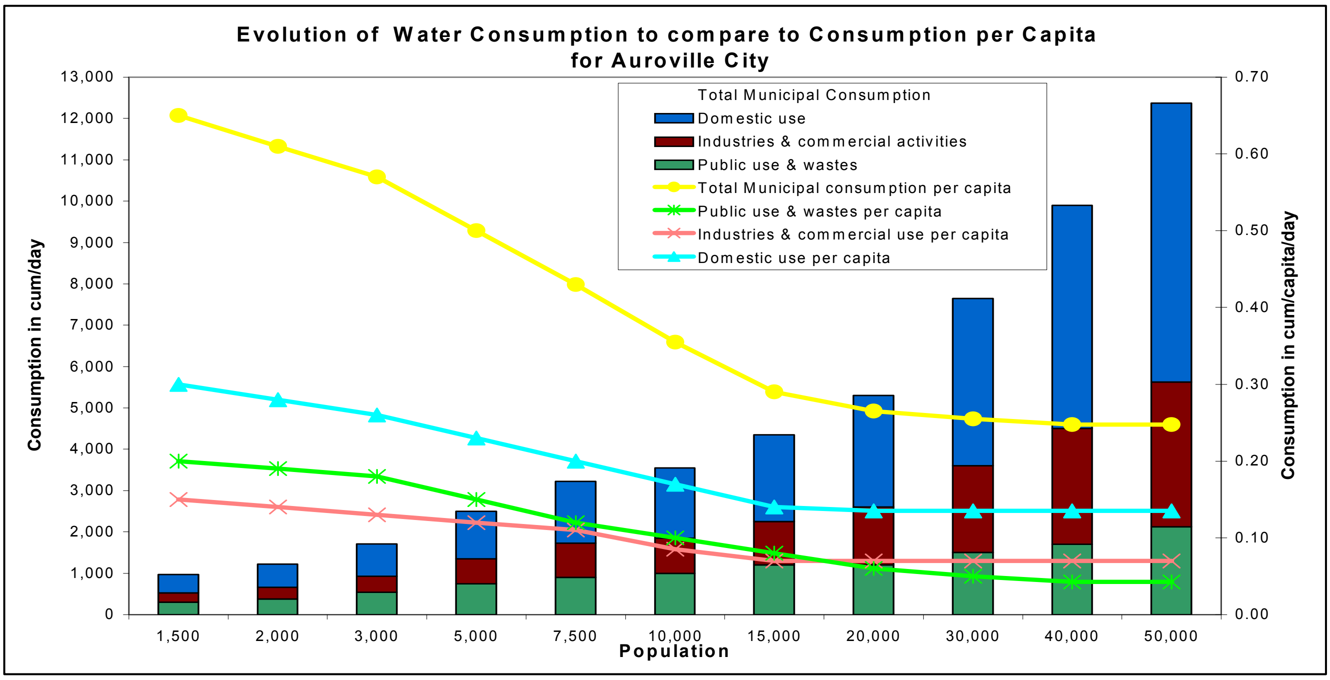
We target the average consumption for Auroville in the future as follow:

	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**

Estimated progression of water consumption

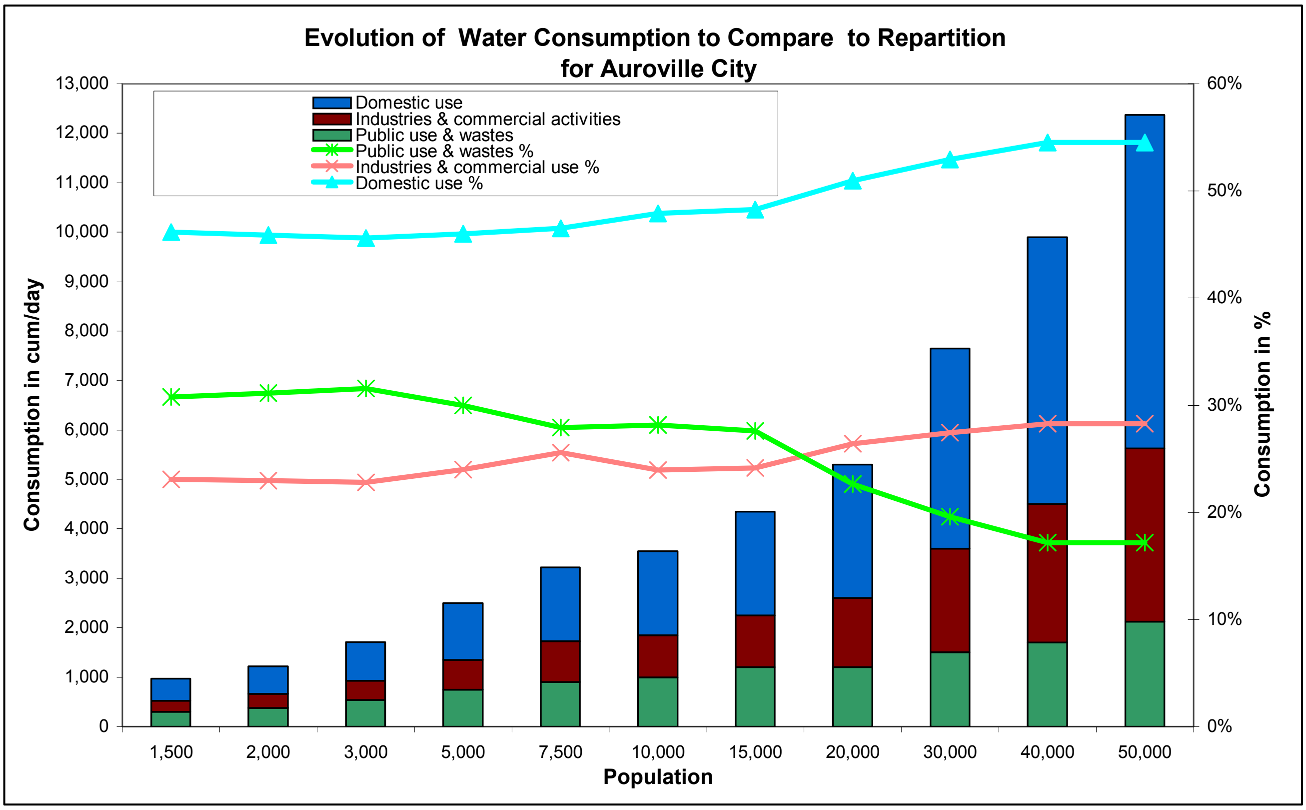
The following graph gives an estimated progression of the water consumption for Auroville city, starting from the actual situation, the anticipated progressive changes and the final above targeted criteria.



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.

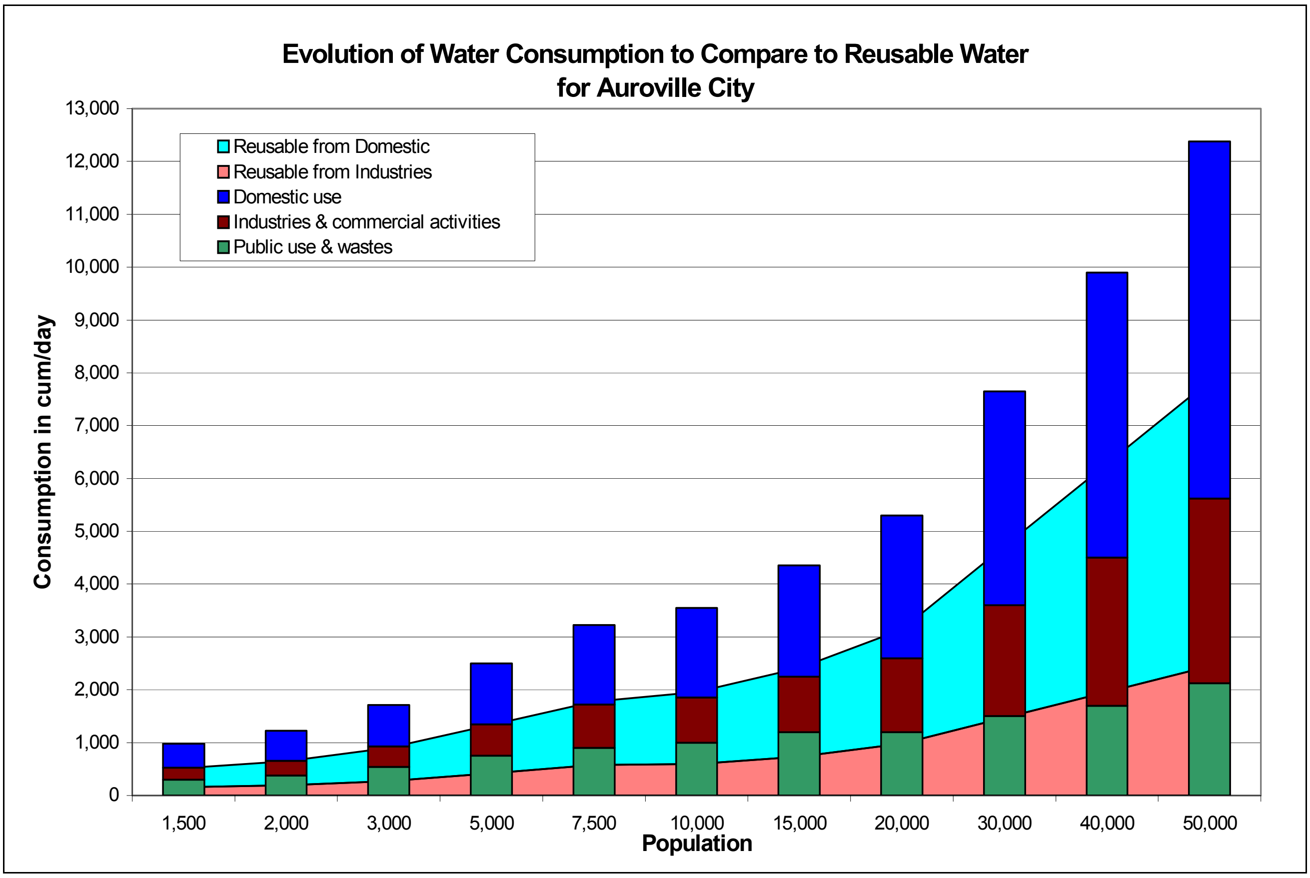
This evaluation has been done according to the fact that Public use and Waste (as defined



paragraph K1) does not require important amount of water if properly conceived, and therefore can lessen according to evolution of the infrastructure.

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.

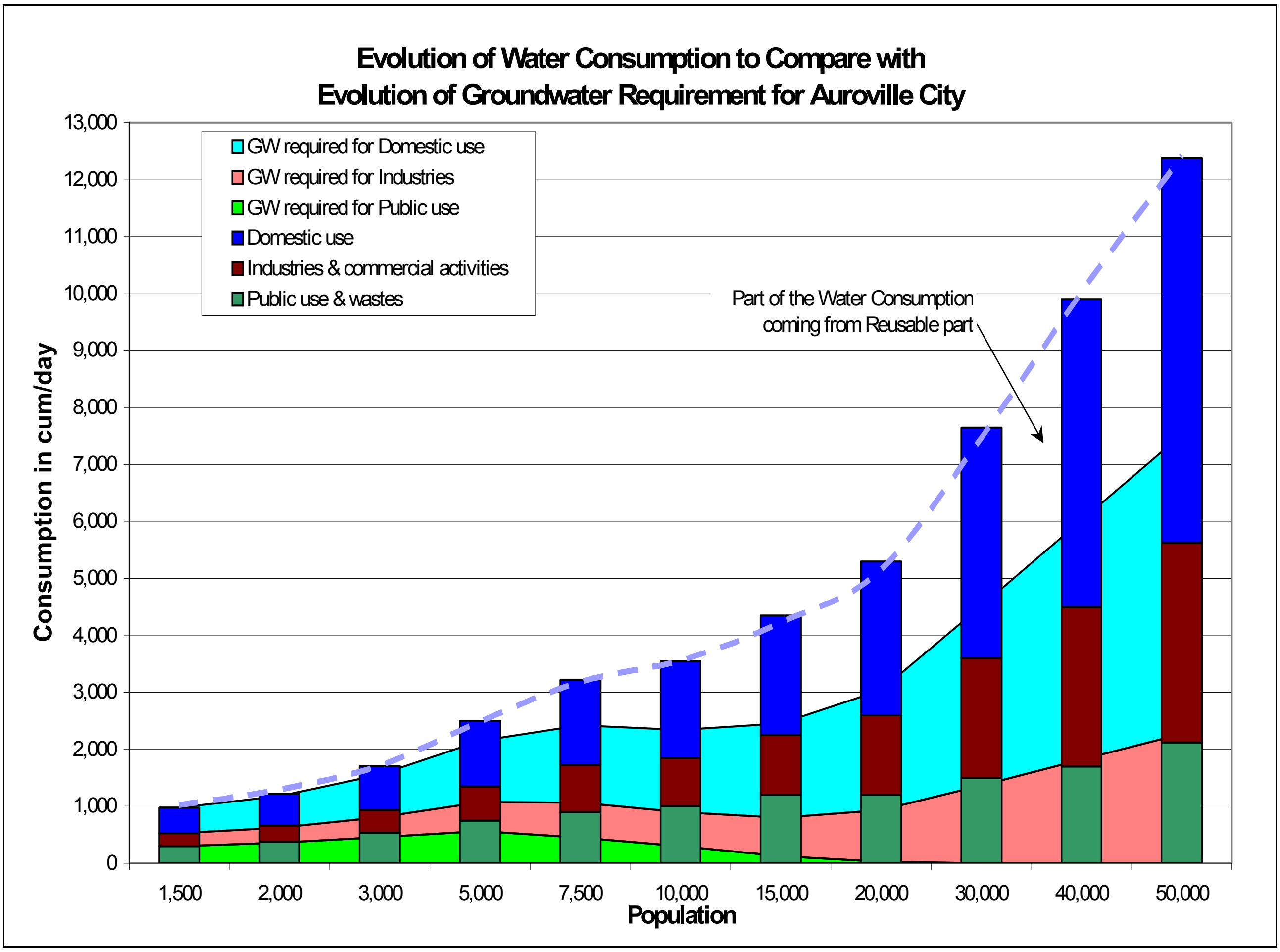
Therefore, we are able to define the requirement of Ground Water for the City area.

Required water production and wells capacity for the city

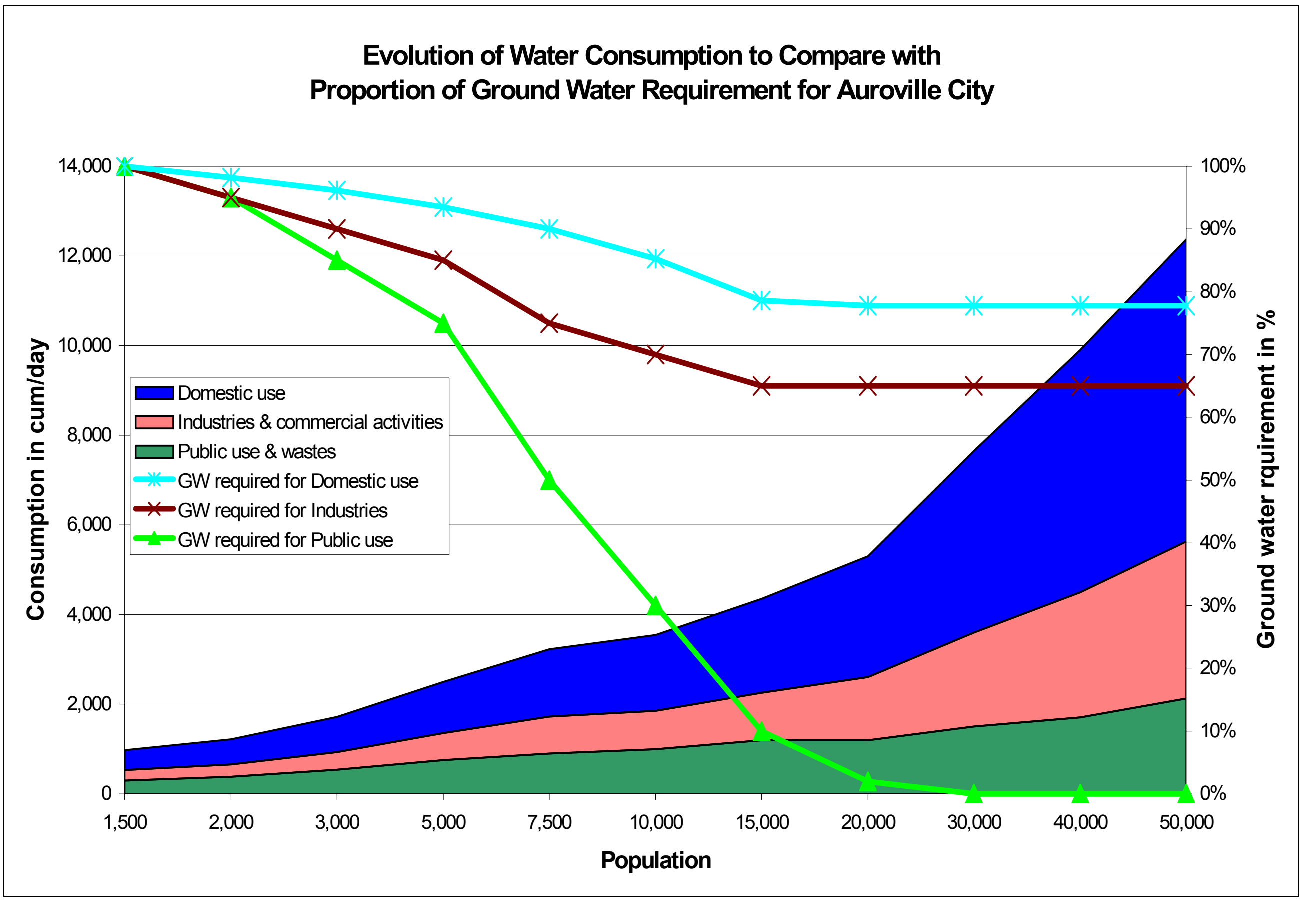
From above analyses, we can assume that from the total water consumption in the city area, around 4,500cum/d can be reused for municipal purpose, 3,000 cum/d for agricultural and green-work purpose on a daily average.

> 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.


Evolution of Water Consumption to Compare with
Proportion of Ground Water Requirement for Auroville City
Consumption in cum/day
Ground water rquirement in %
Population
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1,500
2,000
3,000
5,000
7,500
10,000
15,000
20,000
30,000
40,000
50,000
Domestic use
Industries & commercial activities
Public use & wastes
GW required for Domestic use
GW required for Industries
GW required for Public use

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.

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 6,000 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
5. 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 …