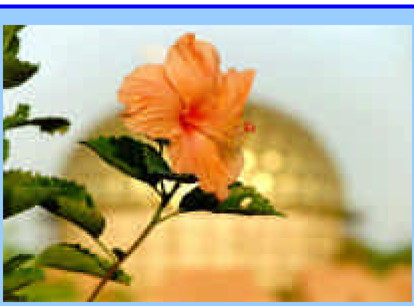

A Model of Water Resource Management for the International Zone Auroville

Why not go for an Integrated Model of Water Resources Management for the International Zone in Auroville?

Views and Assessments

Auroville Water Service Harvest
Corrected Version - 15th July 2004

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A Model of Water Resource Management for the International Zone of Auroville

Some Views and Assessments

1. Auroville belongs to nobody in particular. Auroville belongs to humanity as a whole. But to live in Auroville, one must be the willing servitor of the Divine Consciousness.
2. Auroville will be the place of an unending education, of constant progress, and a you th that never ages.
3. Auroville wants to be the bridge between the past and the future. Taking advantage of all discoveries from without and from within, Auroville will boldly spring towards future realisations.
4. Auroville will be a site of material and spiritual researches for a living embodiment o f an actual Human Unity.

The International Zone Group together with Auroville International Germany has requested Auroville Water Service - Harvest to develop a concept of water resource management for the zone.

Sustainability should be the basis of the entire concept, with a clear impetus toward minimized demand on the severely damaged groundwater.

Understand the problems clearly before seeking solutions.

Transparency in the reflection process, suggestions, choices and implications is the basis for an evolutive development.

The International Zone is envisaged as a model of sustainable water resource management. Keeping this in mind, the major, underlying factors to this study are:

- No finalized master plan or general layout exists yet for this zone. This document is consequently a bottom–up approach. However, it cannot replace planning and development studies.
- For the same reason, an engineering design is unfeasible at this stage.
- No sustainable city exists in the world so far. The need for appropriate references is therefore critical to validate the methodology.
- Auroville has an unpredictable growth rate. The concept as well as the selection of technology must therefore provide room for further improvement and evolution of the techniques and understanding.
- A correct evaluation of the activities in the area (quantity-wise and quality-wise), including a major, potential shift, is needed to determine the most suitable solutions and combination of solutions.
- The affordability as well as the replicability of the resulting proposal is indispensable in the Auroville perspective.
- Apart from serving the needs of the International Zone, the proposed concept should be advantageous to the surrounding population, or at least not detrimental.
- Delineation of environmental sensitivity is to be developed.
- Kottakarai village and related colonies are key concerns of this area and must be included in the overall approach to water management.

The outcome of sustainable water systems includes smaller scale water systems, lower upfront capital costs, more community involvement and awareness.

A Systemic methodology, allowing enough flexibility for unpredictable conditions and non-desirable, cumulative reliance will follow.

Thanks

I would like to express my sincere thanks to the students and professionals involved in the realization of this document and their (sometime) amusing tone:

On an exchange program from the University of Washington

- Matthew S. Raske, for his comprehensive document on stormwater management
- Paul Roberts, for the very crucial landscaping aspect
- Coy Morris, for his compilation on wastewater management

From the Geo-common program and coming from the University of Oregon

- Sara Albee, for the ongoing effort to understand the village situation and the necessity for integration into our water management concept.

From the University of Applied Sciences and Berlin Business School

- Steffen Blume, for the coordination of the students, and his valuable participation in the sanitation and the rainwater harvesting sections.

Diploma engineer in landscape architecture from Germany

- Anja Krause, on her very meticulous research on plants appropriate to the International Zone landscape.

Naturally, I extend my thanks to Harvest's team, and particularly to Sivasubramanian, Selvam, Pierre Jorcin and Bovaneshvaram for their dedication and kindness.

My infinite gratitude to Mother, who creates this ever-challenging place and imperishable Dream of the Divine.

Gilles Boulicot, Auroville, 24th April 2004.

Introduction

"Of all our natural resources, water has become the most precious. In an age when man has forgotten his origins and is blind even to his most essential need for survival, water along with other resources has become the victim of his indifference."[1]

Without the cooling down of the atmosphere and the resulting condensation of water into clouds, life as we know it would not have been possible. The clouds released their contents and the water rained on the earth. Water became creeks and rivers always running down towards the lower places. Filling up the lowest parts of the earth's surface, the earth became the blue planet. Inside the ocean, life evolved about 3.7-2.5 billion years ago. Slowly, life crept onto rocky surfaces and evolution proceeded. One might say: Where water exists on this planet, life is possible. Where no water exists, no life is possible.

The latest result of evolution is called *Homo sapiens sapiens.* The story of his evolution was a glory. In the early days, he learned how to use tools, how to communicate and how to make things work for him. Today, he has developed a very complex social and economical structure; he designs life through genetic manipulation and recently launched a spacecraft on Mars. However paradoxical it may seem, it is also true that the most intelligent life that has ever been on earth destroys its own source of life.

To reverse this paradigm and to build a humanity and a place generating constant progress with a positive impact is the task at hand.

[1] Carson, Rachel, 1962, "Silent Spring" Houghton Mifflin

A. Purpose of the Research

The purpose of this document is to initiate reflections on Integrated Sustainable Water Management for the International Zone of Auroville. It is a very challenging task, as there is no sustainable city existing on earth from which to draw an example.

This document analyzes the features of the International Zone systematically and consequently the solutions fitting with the needs and defined criteria. It gives the reader a general understanding about the ground reality and is essentially aiming at environmentally sound development.

To create the notions of development on an appropriate footing, it is also intended to work out an appropriate methodology by offering clear, logical and transparent thoughts at each step. This should allow us to maintain the validity of the reflection at a later stage and to incorporate new advances in techniques, or even create new techniques or new frames of mind, without setting aside the validity of the original reflection. Moreover, the practicality and strength of the method should permit it to be extended to other areas.

In each chapter, after a description of the subject and its validity in the local context, there is a discussion of different methods or technologies. Each chapter closes with reflections, recommendations and conclusions according to the ground reality.

After reading this document, the reader should have a clear understanding of the difficulties and problems of this area and the promising, emerging solutions. He or she should also be stimulated to envisage the integration of such and such a technique within a particular context.

All together, it is a challenging task!

However, this document does not claim to stand as a feasibility study for obvious reasons. Further studies and decisions are necessary to clarify the situation before coming to a consolidated range of solutions.

When going through the text, it is essential that the reader keep this framework in mind.

B. Limits of the Research

This document is understood as the basis for creating a suitable planning and development process. It does not come up with an ultimate solution for water issues.

It is categorically not envisaged as an engineering design document, which would be unrealistic at this stage. It is written in general terms, in order to give a range of possibilities for the not-yet-planned International Zone.

Further studies and research are required in several fields.

The solutions presented can be integrated on any scale, which may be appreciable to validate the method and its components. However, they can only be operational with the launching of the planning component.

C. Methods of Research

The authors generated their knowledge out of literature, case studies, available research conclusions in the area and interviews. The members of the International Zone Group, especially planners and architects, were contacted. Villagers, including women and young people, were approached. The groundwater and GIS teams of Harvest generated detailed geological and hydrological information and thematic maps.

This document is a compilation of studies conducted by several people. Accordingly, the tone of each chapter may be rather different, as well as how the subjects are treated!

D. Components

1. Storm water management and erosion control

Storm water management and erosion control are the most well developed environmental practice in Auroville, but not practiced that much in the International Zone.

The methods developed so far, i.e. field bunding, planting and check dams, are not appropriate in their actual forms for urbanized areas. Landscaping must be done in a very proper way and not create contradictory conditions for the environment as well as the activities going on.

This area is linked to the main agricultural zone of Auroville. It would therefore make sense to design a storm water management system generating a positive impact on the nearby Irumbai ery (irrigation tank) and its command area, together with techniques for efficient groundwater recharge and erosion control.

The runoff coefficient of this area is around 0.30 in the actual conditions, while it may reach 0.50 when the area is fully developed, if no measures are taken to counterbalance the effect of an increasing, impervious area. Such negative conditions may generate erosion, flood, pollution and may force the development of large and costly infrastructure. On the other side, the best storm water control (in fact inseparable from appropriate landscaping and sanitation) may offer suitable conditions for a trouble-free effect on the area and its surroundings.

2. Landscaping, Irrigation and Appropriate plant species

Low water consumption landscaping like “Xeriscape” is definitively a concept to integrate in the water management of this zone. Natural ventilation and a cooling effect, including shaded paths and pleasant surroundings must be the outcome of such a practice.

A detailed list of plants, taking into consideration both appropriate water usage and beautification, is integrated in this document.

3. Rainwater harvesting

It is now compulsory under the ordinance of the Tamil Nadu Government and may well be a major resource of water in such a context, providing it is affordable.

About 960mm of rainwater (on an average yearly rainfall of 1,281mm/y) can be collected successfully per square meter of roof (long-term average), which offers a large range of supply. The main difficulty is the limited and concentrated number of rainy days of adequate quantity (24 rainy days can potentially be harvested out of an average 62 rainy days per year, mainly during the northeast monsoon).

4. Sanitation

Eco-sanitation is most probably a very appropriate choice for many activities foreseen in the International Zone: there will be plenty of public buildings and related toilets will be one of the main consumers of water if not built in a sustainable way.

Upstream control by the systematic installation of low water-consuming devices is a very effective and simple way to reduce pollution (together with reduced water demand) and must be a common practice.

5. Wastewater management

Various decentralized techniques are available in Auroville. It is recommended to go for those that use less space and lose the least amount of water. Onsite management is certainly to be considered, with a clear impetuous toward recycling.

6. Distribution & Consumption

Today, Auroville shows very high level of water consumption per capita. A strong effort is needed to reduce it to a reasonable level.

It is very likely that several distribution systems will have to be developed in accordance with the various needs, and these in accordance with various water quality requirements. The appropriate magnitude of multiple distribution systems must be looked at carefully, which implies the necessity for segregation of usages.

7. Fresh Water resources management

Due to the specific soil and geological conditions in the International Zone, subsurface water management seems promising.

Groundwater resource management is where the entire concept must end, by allowing as little stress as possible on this badly affected, natural resource.

Groundwater in Auroville is naturally of high quality and must be preserved at any cost.

8. Villages

One of the most staggering situations of our development is the lack of definition of the villages' role and their integration in the overall planning exercise. This issue is particularly crucial in the International Zone because of the presence of Kottakarai and its extensions.

While it is important for the general layout and the integration of the various physical and socio-economical components of the zone, the consequences on environmental issues, chiefly water, are striking.

9. Other elements

To be aligned with a sustainable approach, several elements should be integrated in the design phase: energy demand, the surfacing of roads and paths, "footprint" of the buildings, activities.

These parts are not integrated at this stage.

E. Basic parameters

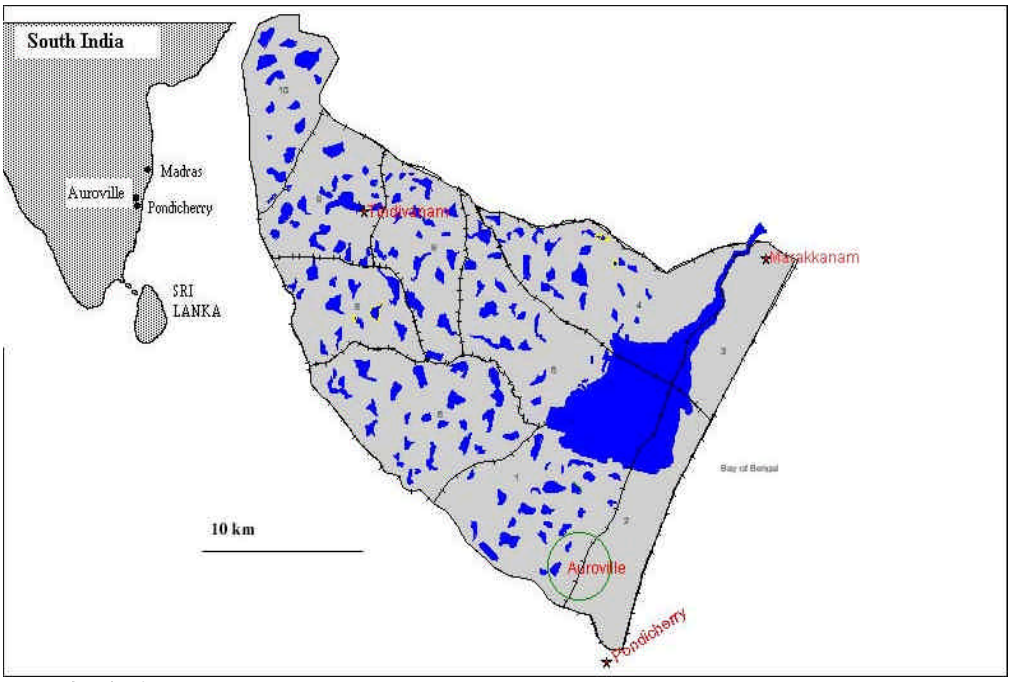
PAVILION AREA OF THE INTERNATIONAL ZONE IN AUROVILLE
LAND USE, DENSITY AND NOS. OF RESIDENTS OR WORKING PLACES
(INCL. RECEPTION CENTRE)

	A		B	C	D	E	F	G	H
	usable surface area as per land use plan (sqm.)	%	to compare : population x production (%)	25% of A green spaces in built up areas (sqm.)	15% of A technical infrastructure (sqm.)	A-(C+D) surface available for buildings (sqm.)	90% of E net surface area (less minor access rds.) (sqm.)	built up area (coverage 50%, FAR=1, no. of floors=2) (sqm.)	no. of places (based on 45 sqm. floor area/pers.) pers.
ASIA (incl. Australia)	**129,003**	47.5	45	32,250	19350	77,403	69,663	**69,663**	**1,548**
EUROPE (incl. Russia)	**65,577**	24.1	23	16,394	9836	39,347	35,412	**35,412**	**787**
THE AMERICAS	**48,710**	17.9	21	12,177	7306	29,227	26,304	**26,304**	**584**
AFRICA (incl. Middle East)	**28,503**	10.5	11	7,126	4275	17,102	15,392	**15,392**	**342**
Total	**271,793**	100	100	67,947	40767	163,079	146,771	**146,771**	**3,261**
RECEPTION CENTRE	**21,736**			5,434	3260	13,042	11,738	**11,738**	**261**
GRAND TOTAL	**293,529**			73,381	44027	176,121	158,509	**158,509**	**3,522**

Note:
We have to expect an additional equal number of people working outside buildings as gardeners, watchmen etc.; this would sum up to a total of 7000 persons working in Pavilions Area and Reception Centre. Amongst them, 600 will be residents (in correspondence with the Auroville Master Plan).
Time horizon: after 5 years: 200 pers., after 10 years 1000 pers, after 25 years 7000 pers.; there are at least 2000-3000 visitors/day to be expected after about 15 years.

11.03.2002/Helmut

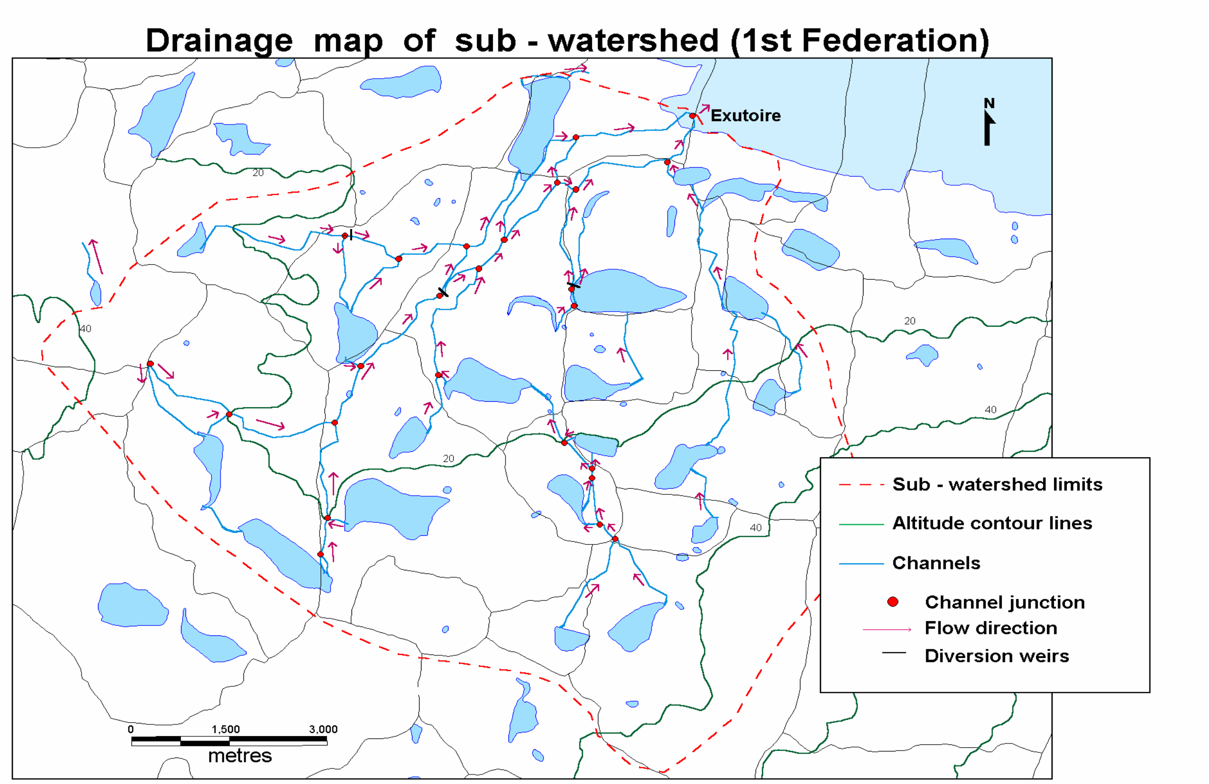
Description of the Area



The watershed of Kaluvelly

Satellite image of the area of Auroville (March 1999)

The IZ has an area of 68 ha and is located in the Western part of Auroville. Auroville is located in the Kaluvelly watershed (pictured on previous page). It is necessary to understand the interconnection of the IZ with this watershed in order to understand the water issues of this specific zone.



Drainage map showing the flow direction of the channels

The entire water system of the Kaluvelly has an area of 762 km^2. Its borders are Marakkanam to the North, Pondicherry to the South, Tindivanam in the West, and 35 km of coastline on the Bay of Bengal to the East. The Kaluvelly Lake with an area of 26 km^2 is one of the biggest and last unpolluted swamps of south India, and it has much ecological relevance for the entire system. There are 196 eris (irrigation tanks), linked by chains of tanks, which are all ending into Kaluvelly swamp. These eris are used through rainwater harvesting for irrigation purposes and act also on groundwater recharge. All together, 13,938 ha^2 of fields are irrigated with these gravity based systems. It is also important for wildlife. *"The lake is a wintering place for migrating water birds (more than 100 different species) and is considered as a wildlife sanctuary."* [3]

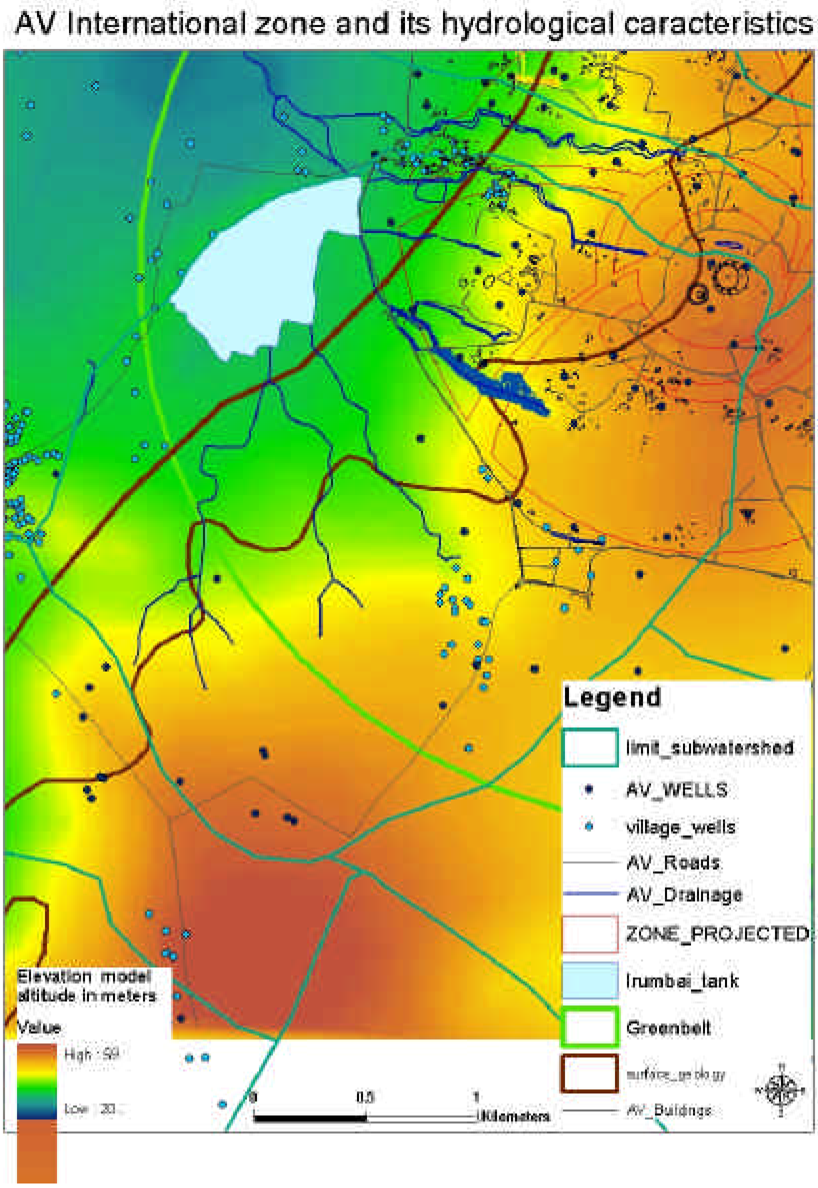
[2] Erxleben,G., 2001, *Wasserkonflikt in Sued-Indien* (Diplomarbeit)

[3] Cuong, Le Quan Minh, 1997, *"Water study and Biological Development in South India", I.S.A.R.A, Lyon*

A. Physical features of the International Zone

The International Zone, located on the West side of the Auroville plateau, is characterized by a smooth and continuous geomorphology with a regular slope towards the west of 15 meters declivity, from 49m to 34 m of altitude (msl), and an average slope of 1.3%.

1. Hydrology



Two main canyons, one in the South and one on the North, determine the main profiles of the zone, while two secondary drains are present in the middle.

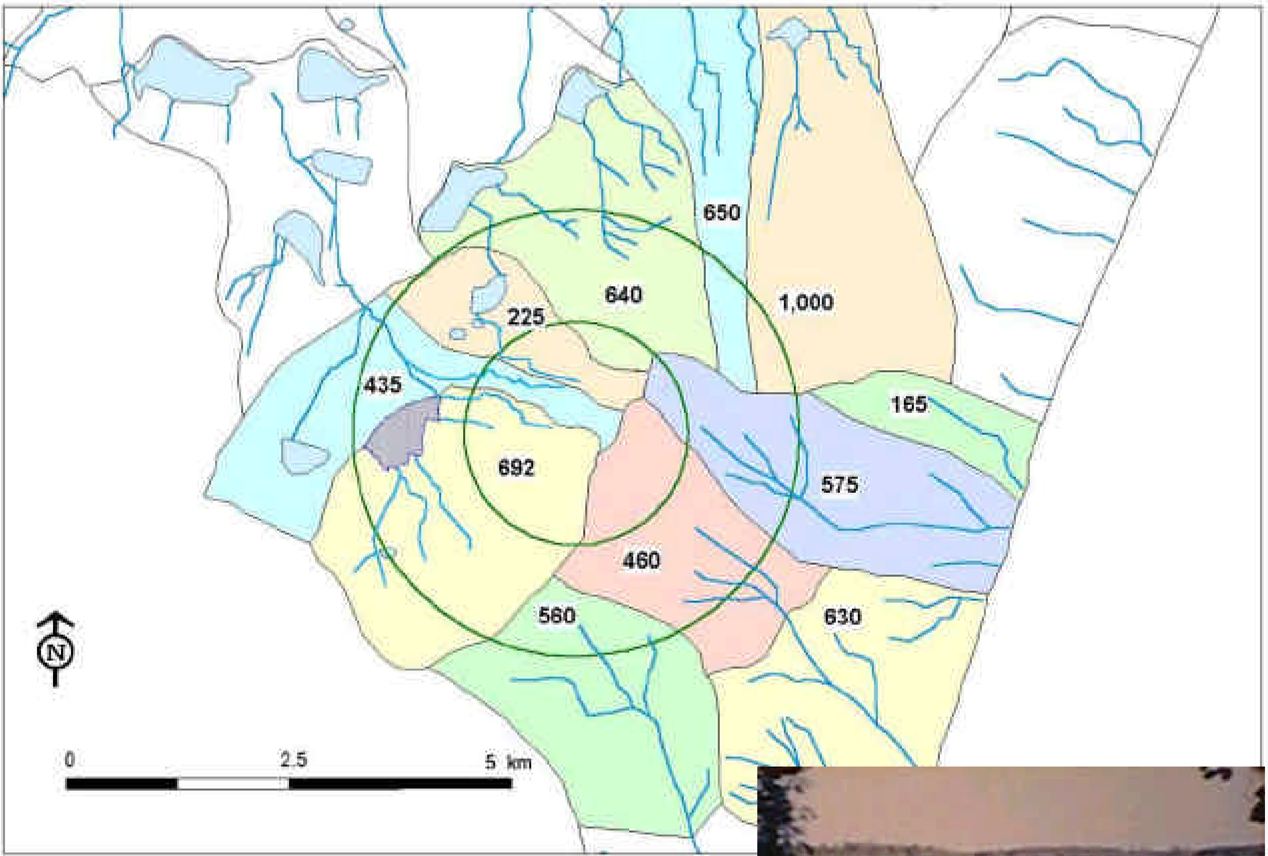
The northern canyon, bordering the Industrial Zone, is in the drainage area of the International Zone. The same canyon passes through the village of Kottakarai and feeds its kolam (pond) after washing the dirt accumulated in it. Because of this precarious situation and the interconnection of the canyon with the underground aquifer, special care must be taken.

The canyon of Aurodam starts in the Residential Zone, but can and must be integrated in the International Zone as well. Its drainage area extends well inside the Residential Zone, making it very dependent on the water management of this area.

The entire International Zone is located on the drainage area of Irumbai tank.

This drainage area, covering 6.92km2, is chiefly included in Auroville's township limits, with 1.83km2 within the city limits and 3.42km2 in the Greenbelt. As per the soil quality, regarding the actual practice and future plans of Auroville's development, this drainage area is highly suitable for agricultural activities.

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



Irumbai tank is the main irrigation device of the area.

Used for flood irrigation, the duration of the water storage is about 120 days, a good value for the area. It offers a maximum storage capacity of 0.480Mm3 for a water sprayed area of 0.370km2 at Full Tank Level.

Irumbai Ery after a good monsoon

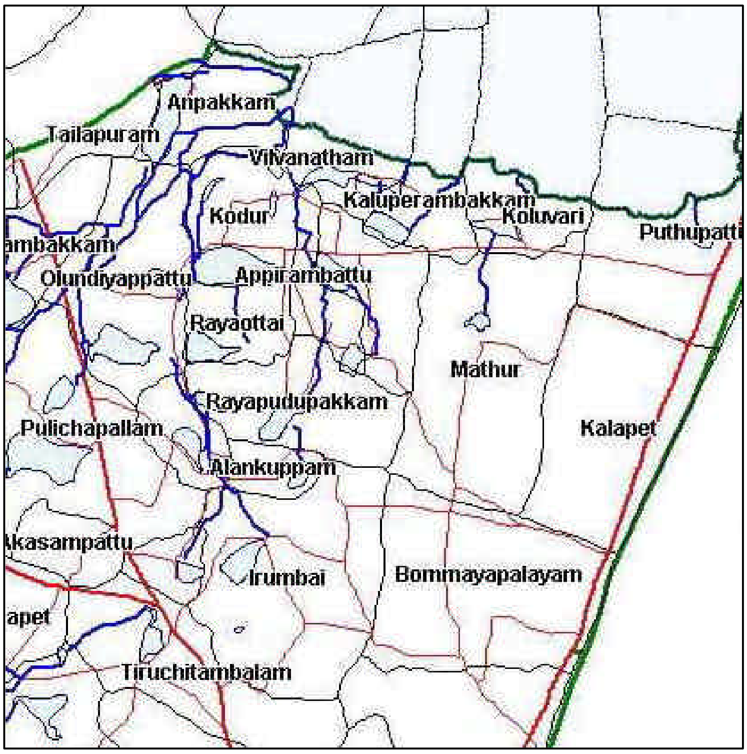
The tank also acts as an important groundwater recharge device, both directly (infiltration through the tank bed) and indirectly (field irrigation).

Fishermen at work at the Irumbai Tank

Irrigation drain in Irumbai Ayacut

Irumbai tank is located upstream from the Kaluvelly swamp. It is part of a chain of irrigation tanks ending in the Kaluvelly swamp.

All the drains of the Zone are directly connected to the Irumbai tank, apart from the northern canyon. It is highly recommended to do the needed alteration to connect this canyon to the tank, as it feeds today a more distant tank, consequently losing water through evaporation and infiltration.



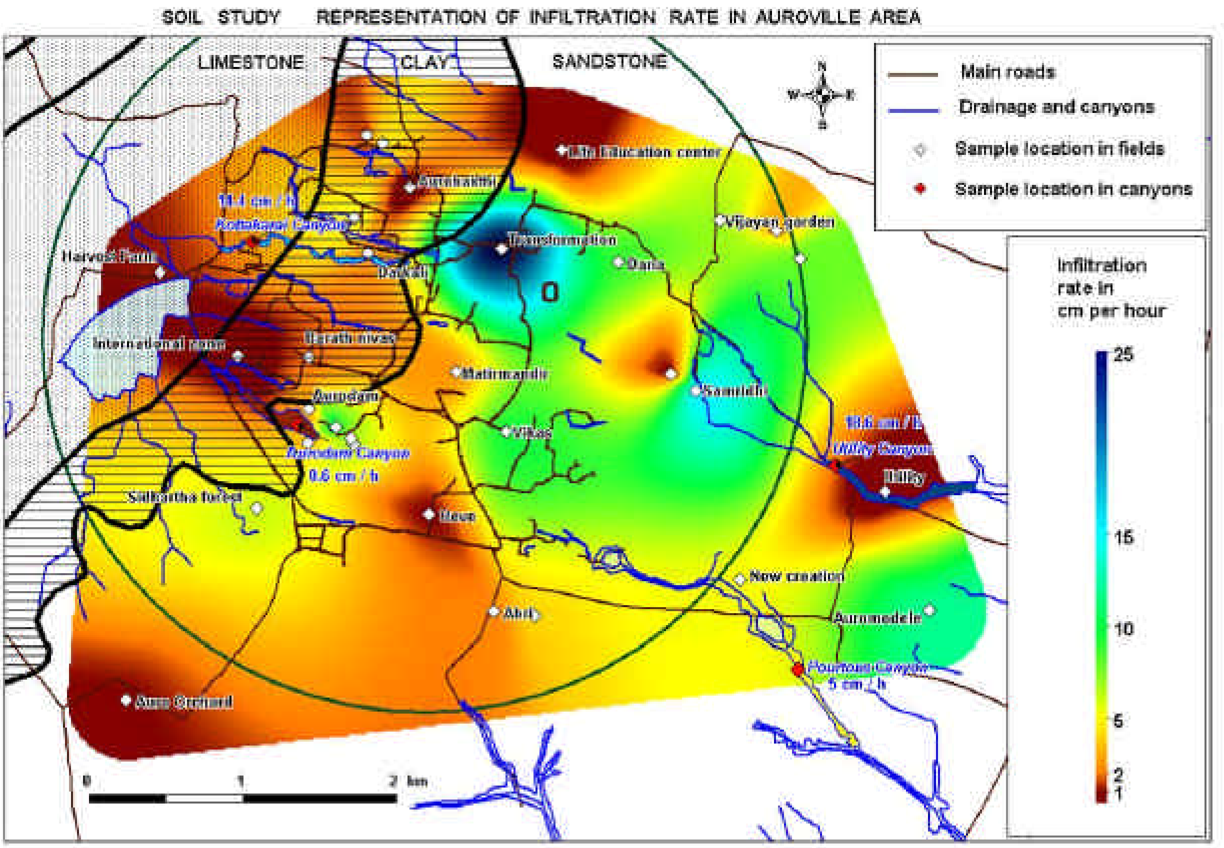
The chain of tank and related drains south of Kaluvelly watershed

Because of this particular hydrologic setup, it is recommendable to develop a stormwater management system matching the agricultural orientation of the surroundings, thus creating a double benefit.

2. Infiltration

The infiltration rate is generally low in the IZ: from 5 to 1cm/h and less. More specifically, it is relatively good in the upper part, due to the geological formation and soil characteristics of the Zone, while it is extremely low in the lower and western part. In fact, because of the low infiltration capacity and the absence of an outlet, the lower area is water-logged after every heavy rain. As per site observation, recharge devices are more effective in some areas, i.e. close to the football field of Aurodam.

The canyons and drains, apart from their natural drainage function, act usually as very effective groundwater recharge devices, mostly because they are developing according to a weakness in the soil, creating a shortcut between the surface and the aquifer. They also create favorable conditions for soil erosion if not properly protected.



The 2 main canyons are equipped with check dams (erosion control) and with an earth dam on the Aurodam canyon (recharge).

Infiltration tests conducted in the area show a large range of infiltration rates, mainly in the canyons (from below 1cm/h to 14cm/h). It seems indispensable to conduct further infiltration tests in a more systematic way (grid).

3. Runoff

If one looks at a specific year, which is well documented, one can see a very interesting picture of the runoff scenario in Auroville emerging.

During the year 2002, the yearly rainfall was 1,012mm, or 79% of the average rainfall for the period 1968-2003. Runoff occurred only twice during this year: once on October 31st (132mm of rain falling in approx. 8 hours), and once on December 6th (199mm of rain falling in approx. 8 hours). This data was measured both in the Eastern and Western sides of Auroville. The soil was relatively dry, mainly for the second event, as it was happening long after the first rainfall.

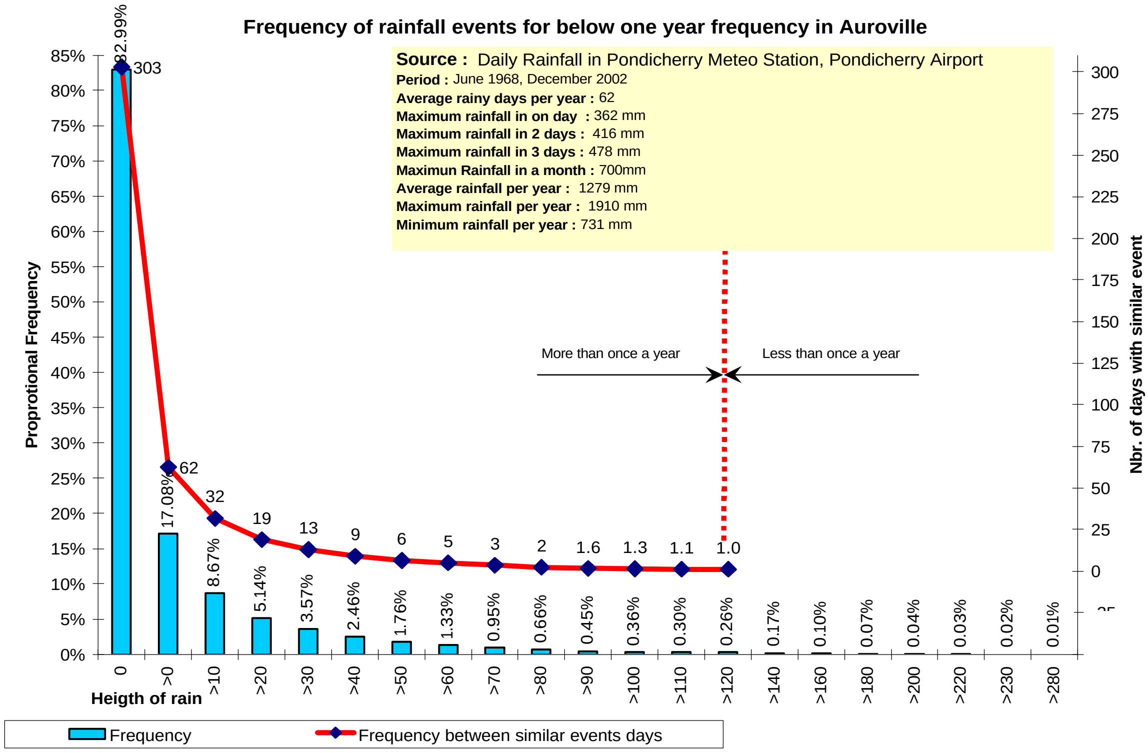
Runoff generated during the second rainfall was evaluated by measuring the accumulated water in Irumbai Tank, which collects all runoff from a clearly defined drainage area of 6.921km² (35% of the Auroville area). The entire International Zone is part of this drainage area.

Initially, the amount of water stored in the lake was of 0.025Mm³, and after the rain it was of 0.291Mm³; which means an additional 0.266Mm³.

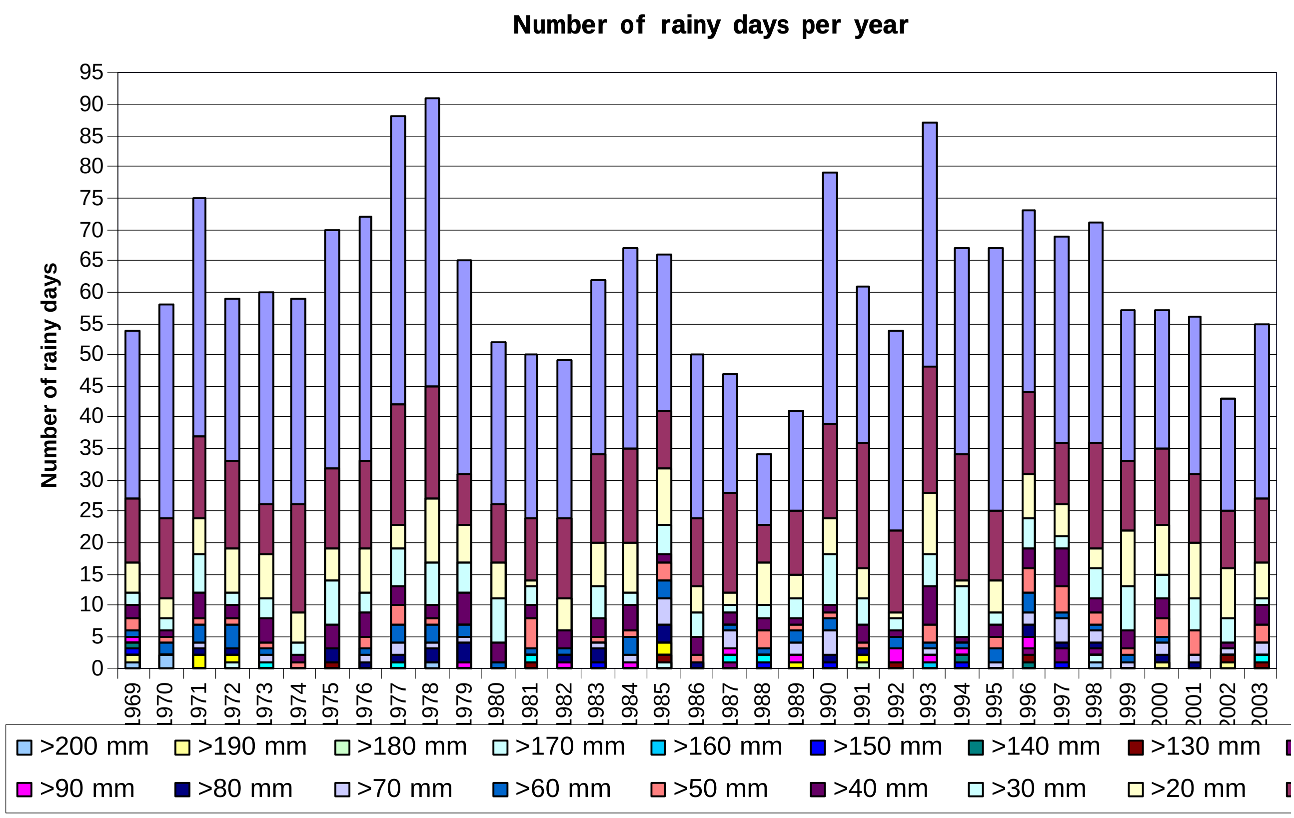
This indicates that out of the 199mm rainfall of 8 hours duration (1.377Mm3 on the entire drained area), 161mm have been intercepted on the land, while 38mm only generated runoff. It means that this specific event has generated the equivalent of 0.754Mm³ of runoff for the entire Auroville area (with greenbelt), while the runoff for this specific year was around 1Mm³. This was confirmed by observations on “Utilité” canyon, on the eastern side of Auroville.

As can be seen, it is relatively a very limited volume!

At this stage, one needs to have a closer look at the daily rainfall repartition to try to assess how often heavy rainfall occurs and what is the potential runoff resulting from it.



What appears from the figure above, is that these two particular events (132mm and 199mm) are infrequent, especially the second one (once in 7 years), and therefore the runoff potential is high.



Of course, this kind of measurement is not sufficient to safely define the runoff yield for the Auroville area, as runoff is influenced by many factors, amongst them the hourly intensity, not reflected there. But we can assume that no runoff is occurring below 20mm of rainfall intensity per hour. Such an isolated event is very unlikely to occur and therefore no runoff should occur from the green area below a relatively important daily rainfall rate.

In the absence of sufficient data on hourly rainfall intensity, it is estimated that runoff can not occur below 70mm of rainfall in a day as a starting point, in the actual conditions. Even in the worse case scenario, it represents a runoff of 23% (300mm) per year. The above analysis demonstrates that the actual value is most likely below 16% or 200mm per year on the average.

To summarise, any storm water management system should be sized to absorb maximum intensity rainfall.

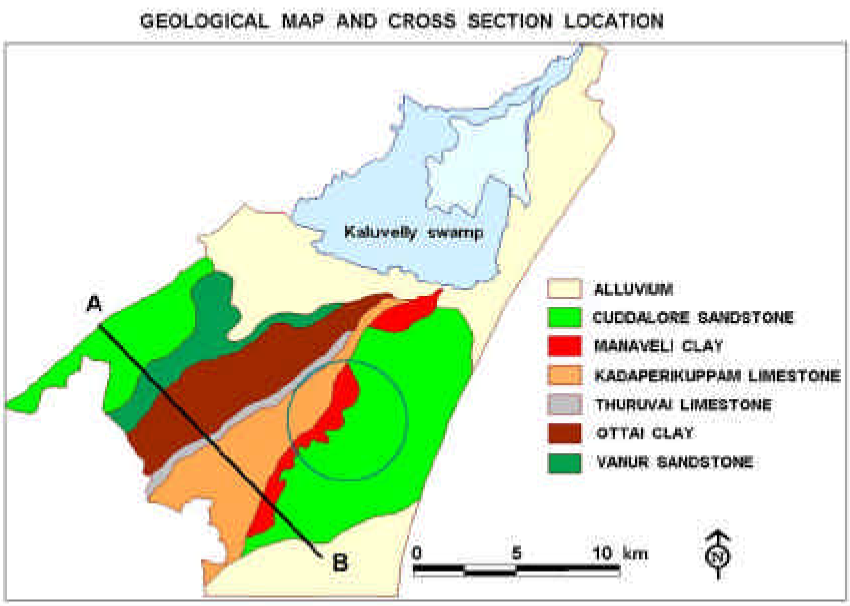
Measured Rainfall data in Auroville Area	**Indian Meteorological Department**
Period : June 1968, December 2003	
Maximum rainfall in on day : 362 mm	
Maximum rainfall in 2 days : 416 mm	Heaviest rainfall in 2 days: 600mm
Maximum rainfall in 3 days : 478 mm	Heaviest rainfall in 3 days: 700mm
Maximum Rainfall in a month : 700mm	
Average rainfall per year : 1279 mm	
Maximum rainfall per year : 1910 mm	
Minimum rainfall per year : 731 mm	
Maximum evaluated hourly rainfall intensity: 60mm	

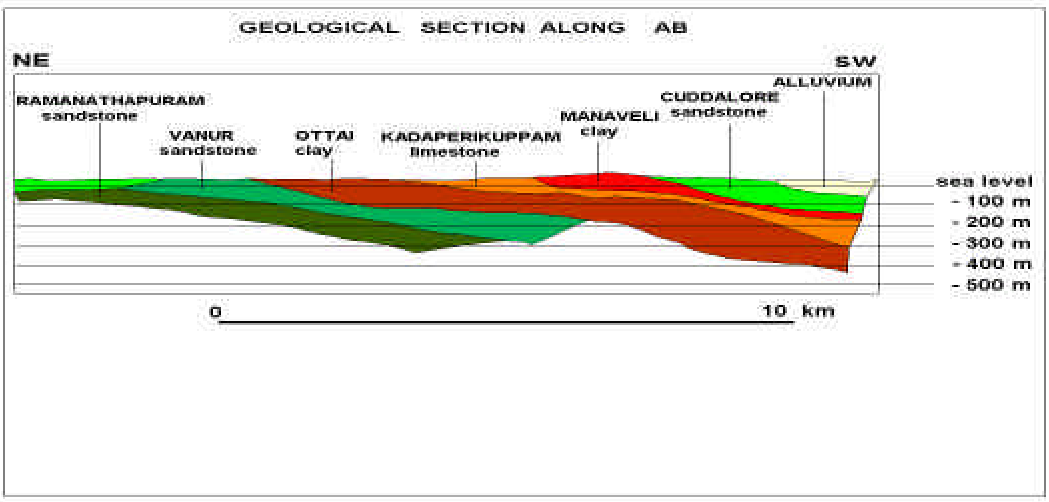
It should also allow, in combination with landscaping techniques, at least to maintain the same runoff proportion as today.

If done properly, the impact on the infrastructure cost and the environment, both in term of local recharge and feeding of Irumbai tank, will be optimal.

4. Geological Setup

In the major part of the Auroville area, sedimentary formations of laterite and sandstones from the Pleistocene and Miopliocene periods are exposed. Sedimentary formations (clay and limestone) from the Pliocene period are exposed in the westernmost part of this area. The Mio-Pliocene and Pliocene formations are demarcated in the following graph based on the study of aerial photos on 1:20,000 scale and selected field checks[4].





[4] CGWB report 1984

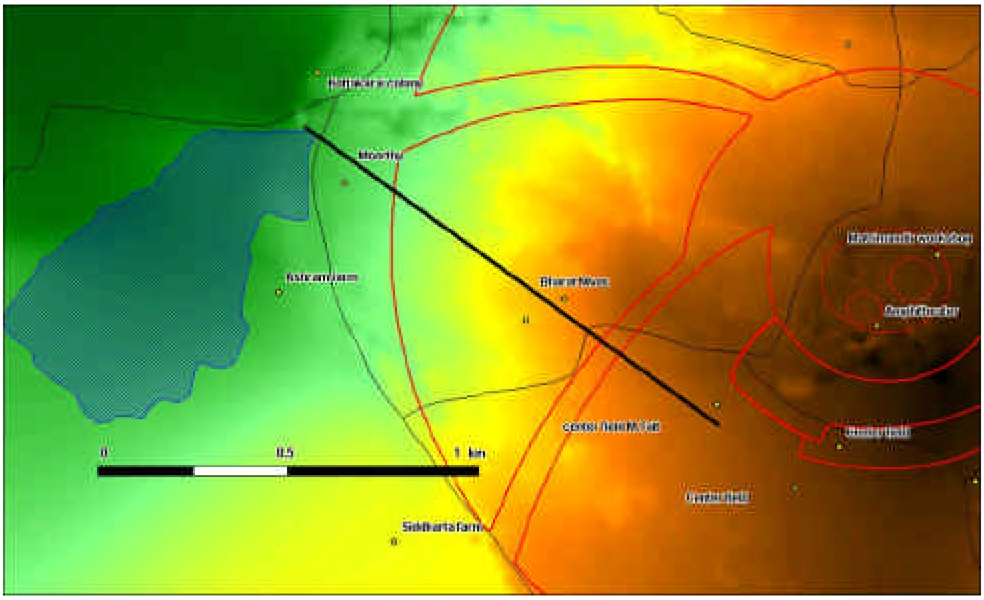
From East to West these geological formations expose many different stratigraphic layers. Each formation has characteristics that need to be recognized including: storage capacity, infiltration rate, permeability, and horizontal transmissivity. It is important to factor these in when planning the future development and uses of this Zone.

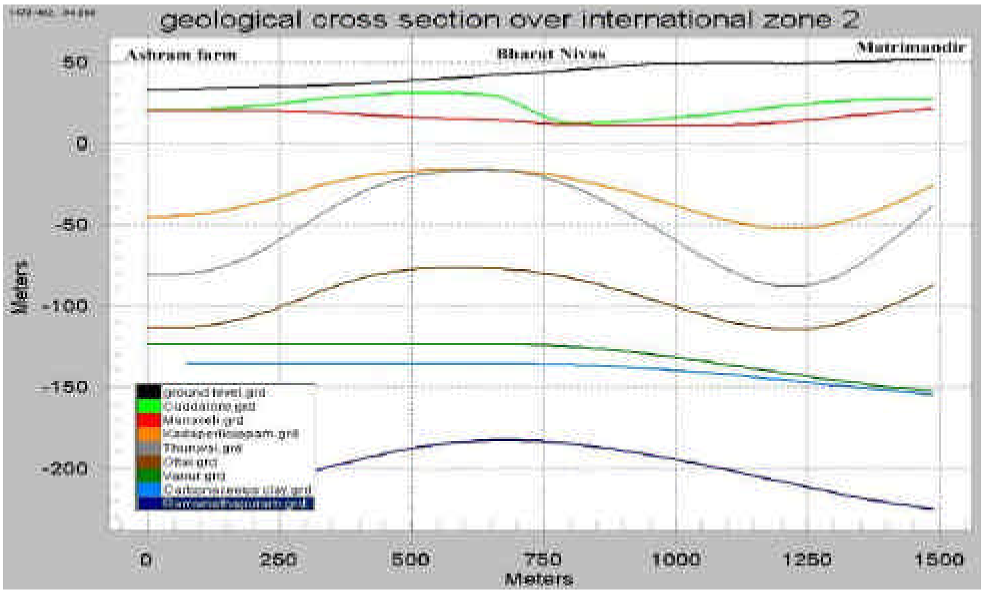
1. Stratigrahic successions

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.

Within the International Zone the higher and eastern region of the Zone is where the Cuddalore aquifer outcrops. On the western edge is the outcropping of the Kadaperikuppam aquifer. The main area is consequently dominated by the outcropping of the Manaveli formation, which covers the majority of the Zone.

By looking at the available geologic and stratigraphic data of the area, we can see the complexity of the setup. For example, the main outcropping area of the Manaveli shows a lot of stratigraphic layers, each one offering various possibilities for storage, infiltration and transmissivity.





While it is today clearly understood that the Manaveli formation is not water tight (aquiclude: an impermeable layer of rock that does not allow water to move through it), it is also clear that most of the time it is acting as an aquitard (part of a geological formation that is of much lower permeability than an aquifer and will not transmit water at a rate sufficient to feed a spring or for economic extraction by a well).

It must be mentioned that sudden changes in the geological structure are predicted in this area, with a corresponding effect on the groundwater availability. The three wells developed around the Visitors Centre are excellent examples of this situation. While the two operating wells offer good and steady yielding capacities, the third one, very close to the existing windmill, has been closed because of an absence of water!

Closer to Aurodam, and possibly in connection with the canyon, the geological profiles and the water level fluctuation indicate an abrupt change which may denote a fault.

The canyon of Kottakarai seems to be closely interconnected with the Kadaperikuppam formation. The protection of this natural feature is therefore essential.

5. Groundwater

"Very great rivers flow underground" (Leonardo da Vinci)

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 man's increasing quest for maximum use of available natural resources had its impact on the ground water, and it is now being excessively extracted without any regulations.

In India, groundwater accounts for more than 50% of the total irrigation area, 80% of drinking water and other domestic requirements and a sizable portion for industrial requirements. Thus the magnitude of ground water extraction is quite obviously causing adverse effects on the hydrologic balance and quality of water.

The studies carried out by Harvest in villages of the Kaluvelly watershed showed disproportionate extraction of groundwater – up to 4 times the average recharge! - and seawater intrusion is observed southward in Pondicherry Territory. The salinity level of the main aquifer (Vanur) is rapidly increasing, reaching unbearable levels even for irrigation purposes.

In most of the villages, the wells supplying drinking water are above OMS and Indian standards as far as salinity is concerned.[5]

Considering the fast depletion of the groundwater and the reversed flow observed for several years, the potential of seawater intrusion in the Auroville area is high and if left unattended would endanger the entire south part of the Kaluvelly watershed.

It must be spelled out that remediation of major seawater intrusion cannot be achieved during one lifetime.

6. Subsurface flow

The very presence of several open wells, mainly at the lower part of the International Zone, indicates a subsurface flow and a relatively low infiltration capacity underneath. Several of these wells, all of them shallow (less than 10m deep), yield large volumes of water throughout the year. Seasonal side springs are also visible in Aurodam canyon, indicating some similar conditions. The horizontal transmissivity should be relatively high if compared to the vertical one.

If subsurface flow is confirmed, the potential of access to a water supply for the International Zone through this particularity cannot be neglected. To ameliorate it means mainly acting on landscaping and stormwater management.

because of the large potential subsurface flow may offer, and because fruther geological data are required, it is indispensable to conduct further geological investigations of the Zone (grid).

[5] Source: Harvest

B. Villages in the Area of the International Zone

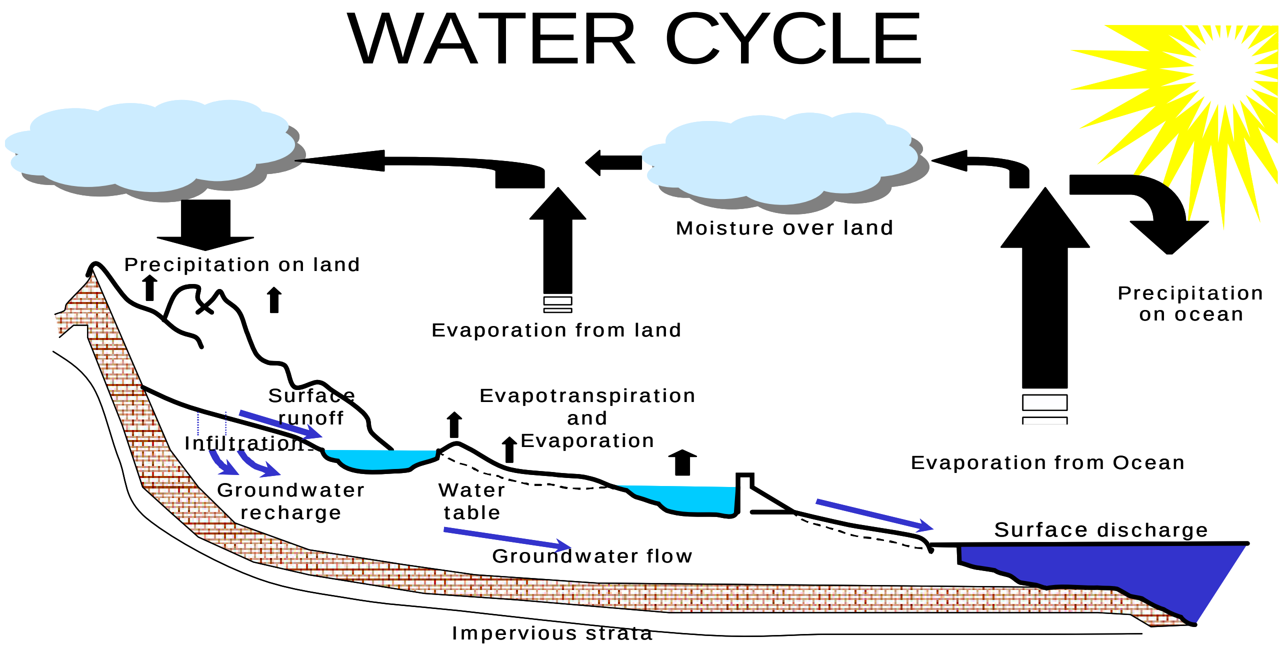
The village is built along the canyon

The IZ area is hosting the main part of Kottakarai village and its extension. Between the Tibetan Pavilion and the first houses of Kottakarai there is a distance of 800m. The village is itself equipped with many open and shallow wells, but also a few deeper wells.

Hardly any sanitation facilities are available, and a lot of waste is going to the canyon. The solid and human waste (as well as animal waste) seeps through the ground to contaminate the groundwater and/or flood directly into the Irumbai tank. For that reason, without considering and integrating the existing population and its activities, sustainable water management is impossible.

Garbage disposal in Kottakarai.

C. Climate



When our only sustainable water resource is rain, without mentioning the unpredictable warming effect, a careful look at our climate reality is helpful. Our area is classified as semi-arid, not because of the shortage of rainfall, but because of the limited number of rainy days.

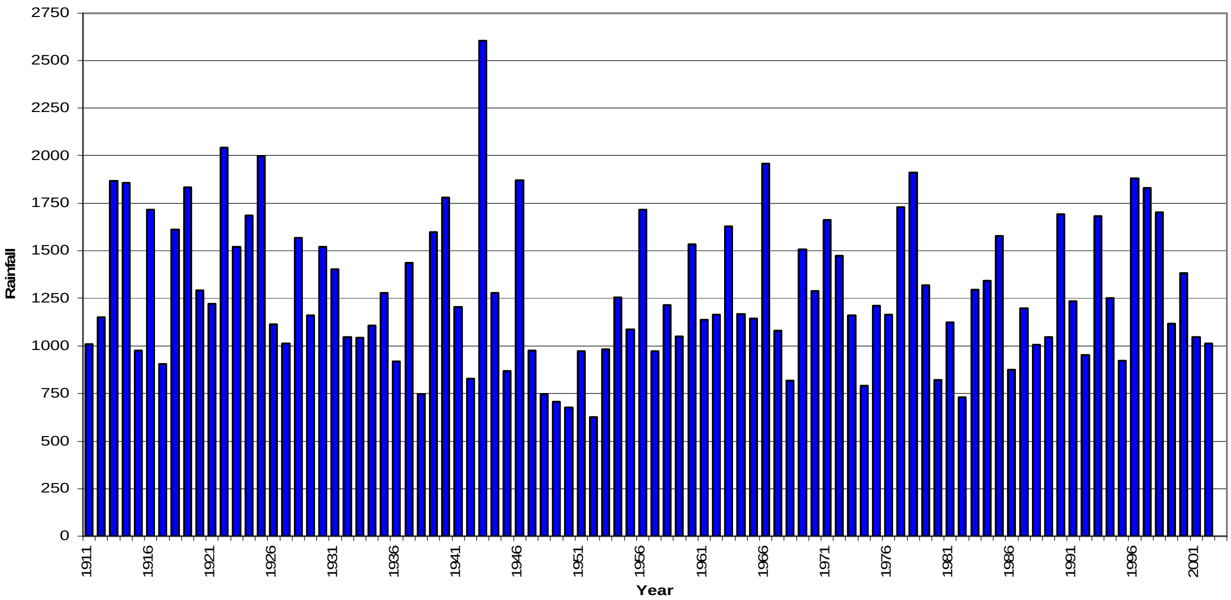
Mean value of meteorological events in Auroville
(calculated from the period 1972-1981)

Months	Temperature deg. celsius	Relative Humidity %		Wind velocity (m/s)
_	_	Morning 8 am	Evening 6 pm	_
Jan	23.5	80	70	9.1
Feb	24.9	82	71	9.8
Mar	26.9	81	71	10.6
Apr	29.3	78	77	14.2
May	31.1	73	77	13.5
Jun	31.4	66	64	12.4
Jul	30.4	74	67	10.7
Aug	29.5	75	70	11.8
Sep	28.5	81	79	9.8
Oct	27.6	86	83	7.6
Nov	25.6	88	80	8.7
Dec	23.8	87	76	9.7

Source: Auroville Station, Certitude

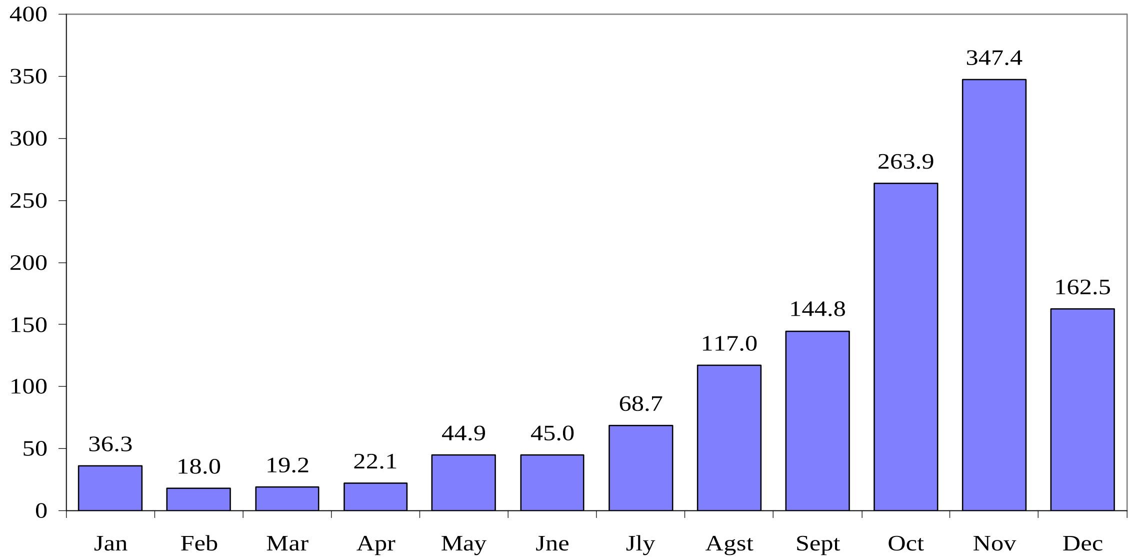
During the years 1911 to 2003, an average rainfall of 1280 mm was measured in the area of Auroville. The year 1942 was the rainiest year with a rainfall of 2,604 mm and then just 8 years later, the least rainy year with a total of 626 mm. The high amplitude shows the irregularity of the rainfall.

Yearly Rain fall from 1911 to 2002

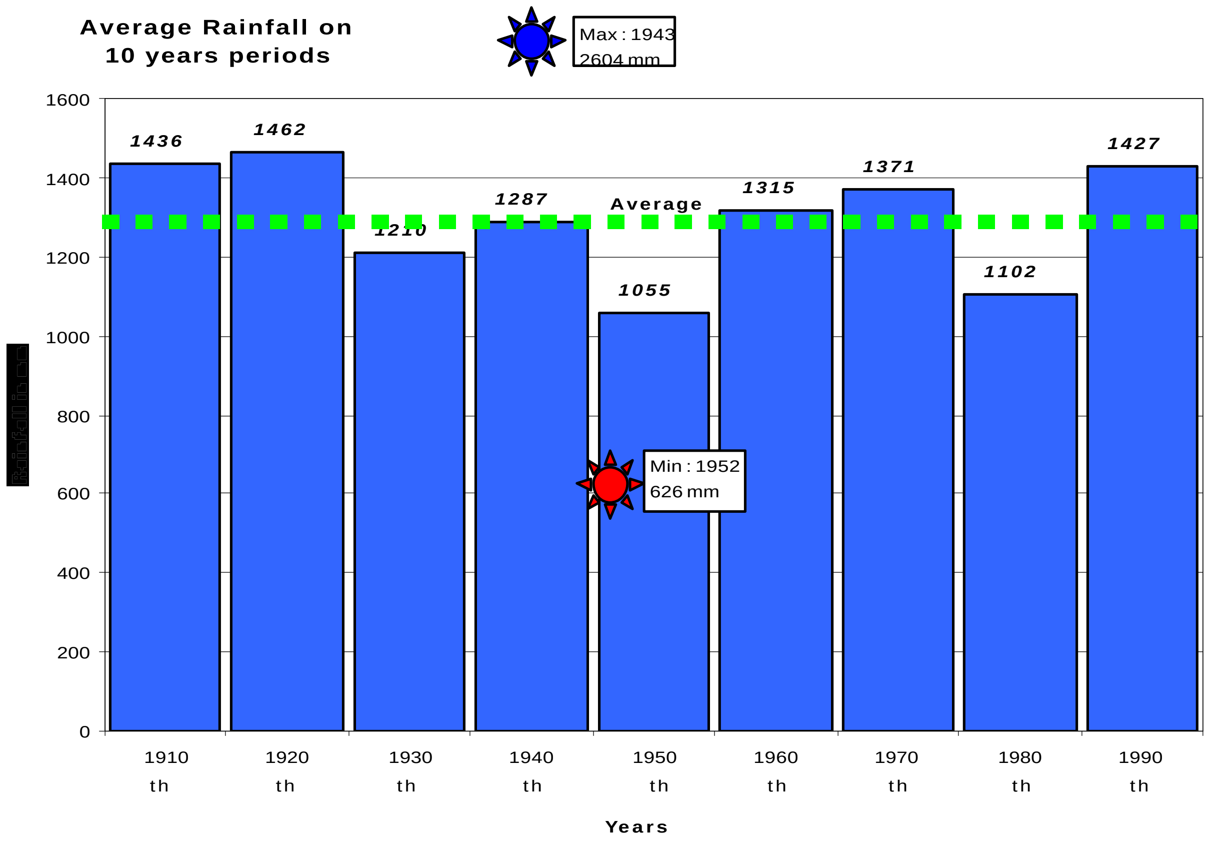


As visible in the table below, most of the rainfall occurs in heavy rainfall activity during the monsoon in October and November.

Monthly Average Rainfall on a 92 years (1911 - 2002) in Auroville area



Even on a long term average, the rainfall pattern shows large variations.



By using rainfall data and other meteorological parameters, one can complete a basic hydro balance, which will help to determine the quantity of rain finally generating runoff or reaching the aquifer.

Hydric Balance from data on 91 years : 1911 à 2001													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
RA	36.3	18.3	19.8	21.8	44.2	45.2	67.1	114.7	141.7	261.6	357.5	165.5	1293.7
PET	77.2	90.7	141.8	203.7	276.1	281.1	251.9	217.6	178.9	156.4	108.3	81	2064.7
R	9.8	2.3	1.3	1	0.6	0	0	2.2	10.7	33	45.4	35	141.3
AET	53.1	20.6	17.1	21.7	36	45.8	67.1	112.5	118	136.5	105.6	75.5	809.5
Effective Rainfall	8.4	5.2	3.7	0.4	8.6	0	0	0	15.1	102.8	239.6	100.3	484.1

RA: Rainfall

PET: Potentail Evapotranspiration

R: Water Reserve. Soil is considered to store max. 50 mm. of water in our area

AET: Actual evapotranspiration

Effective Rainfall: the part of the rain generating either runoff or recharge

It is very clear at this stage that runoff and recharge appear chiefly during the winter monsoon. It is clear too that the volume concerned is very limited if compared to the initial rainfall (37%).

By including the details on infiltration potential, one comes to the conclusion that the sustainability of such a system is very limited.

Input & Output of the system for the data 1911- 2001				
	Input		Output	
	(mm. $year^{-1}$)	% rain	(mm. $year^{-1}$)	% rain
RA	1293.7	100		
AET			809.5	62.6
Effective Rainfall	484.1	37.4		
Infiltration	137.2	10.6		
Runoff			346.9	26.8
RA: Rainfall				
AET: Actual evapotranspiration				

While the above tables are significant for the larger Auroville area, the same is not true for Auroville itself and moreover for the International Zone: the tremendous effort of afforestation, field bunding and erosion control is visibly very positive as the runoff generated from the Auroville plateau is much more limited than what this figure gives, close to 10% for the Zone itself.

However,, due to the potential imperviousness of the Zone, it is essential to create a positive, environmental impact by integrating sound storm water management techniques in development plans.

A careful study of climatic data, topography, soil characteristics, together with planned development, should lead to an integrated design of water resource management, and focus the evolution of development in the Auroville are toward a positive future.

D. Toward Sustainability?

The ultimate source of water in the Auroville area is rain, as everywhere else in the world. This affirmation is even truer here because of the absence of perennial rivers 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 the groundwater of this area, the specificity and functioning of a multiple aquifer system in a 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 this area shows very surprisingly that the actual source of salinisation of our most promising aquifer is not due to sea water intrusion yet.

Eroded land

What is well known is that the ongoing extraction is largely exceeding the annual recharge in most of the area.

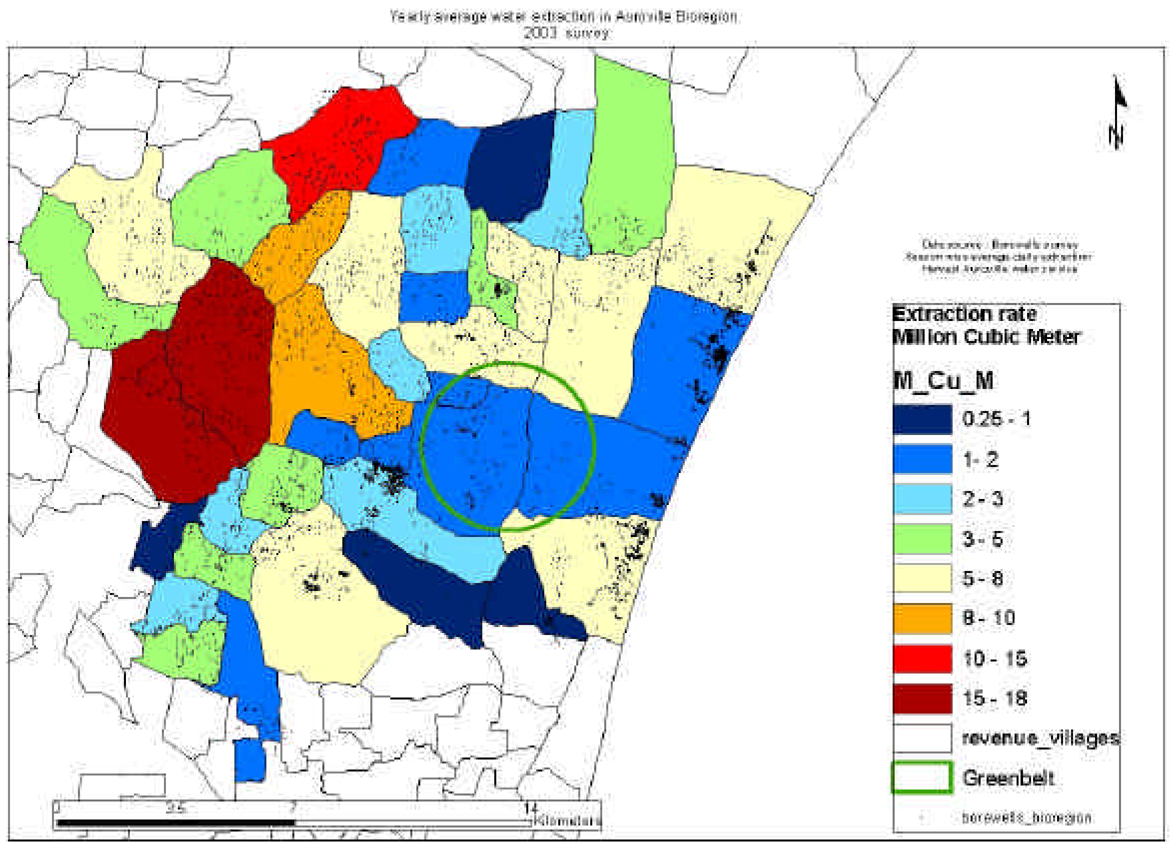
The recharge itself is going down because of the general degradation of the traditional storage structures (erys), interconnection channels and drains, as well as bad soil conservation and irrigation practices.

The most efficient and cheapest way to recharge the aquifer is by the traditional tank irrigation practice, today over and over again replaced by groundwater irrigation.

The tendency is clearly toward further degradation both in quality and in quantity: further well development, over extraction, pollution through fertilizers and pesticides as well as chemicals from various industrial sites are the various strains put on the ecosystem and more precisely the water.

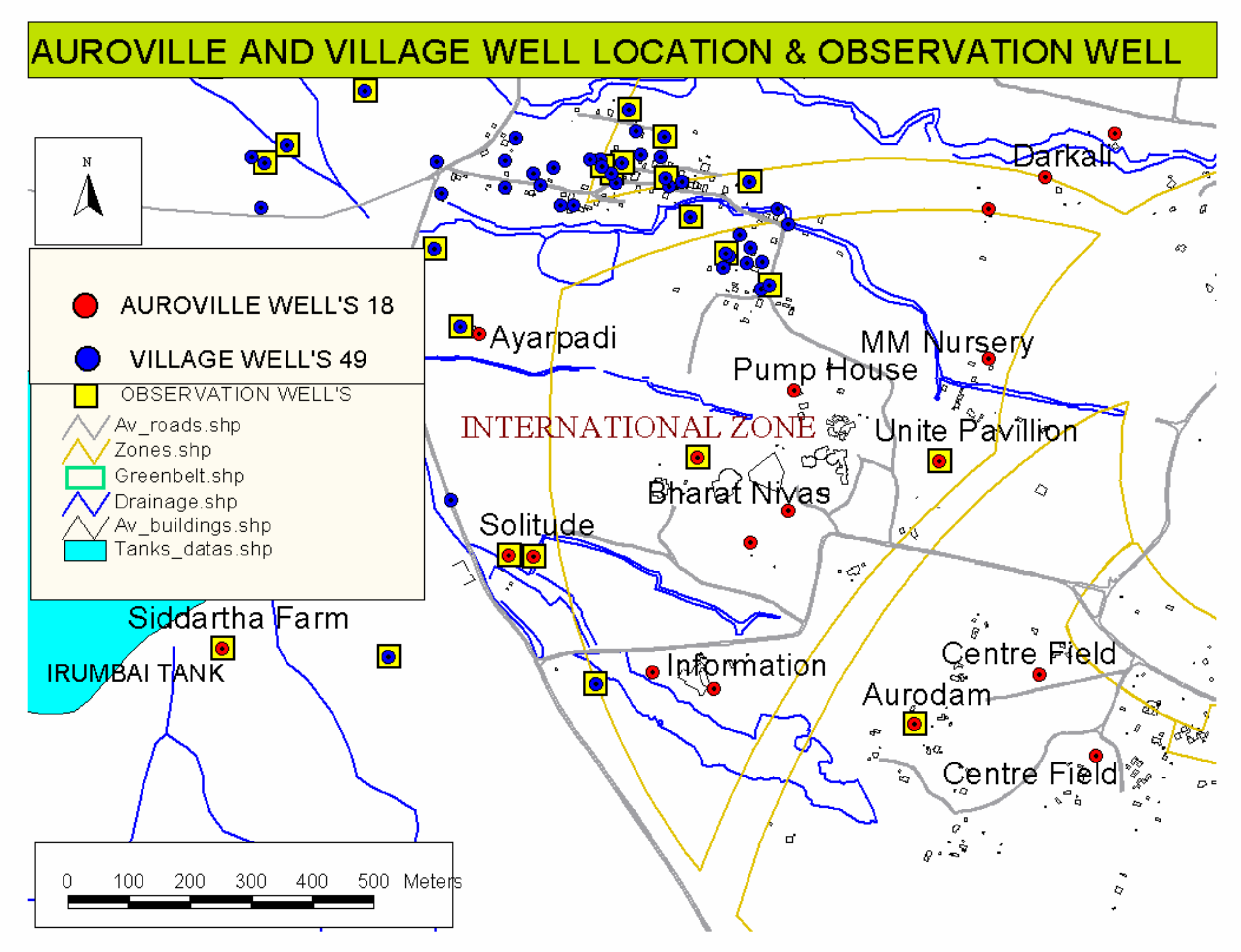
Total irreversibility is, however, possible even with drastic and rapid changes in human behavior. Nevertheless, it will take time to come back to a healthy situation.

With that in perspective, the area of concern cannot at any rate be limited to Auroville. The groundwater exploited in Auroville is the same exploited in the surrounding villages and land. It is therefore very much affected by the general degradation and bad practices of its surroundings. In order to effectively solve the problems around water and sustain the existing groundwater resources in Auroville, the broader area must be integrated into every planning exercise.



Groundwater extraction in Auroville **area**

It is therefore of primary importance to understand the level of interaction of such a complex system and to come up with an appropriate management plan for the resources without dispossessing the other users, but helping them and encouraging them in the same way.



Daily average extraction rate	Nb. of functioning well	Extraction m3/day
Auroville wells in the IZ:	13	192
Village wells in IZ:	49	587
Cumulative average extraction rate for extended IZ:	62	779

At this stage it is good to mention that the immediate problem is not the availability of the water resource, but its sharing and appropriate use.

Auroville has been created to conduct research and to disseminate the results of this research. The neighborhood should be the first beneficiary of such a positive approach.

Environmental sensitivity assessment key as far as wastewater is concerned

A	**Wastewater management zone. Includes the entire service area of the zone if any.**
B	**Receiving environment. Receiving water to which the wastewater is discharged.**
C	**Fate of ground water discharge** **The treated discharge to ground water may enter the regional flow or become base flow to surface water. Ground water flow direction can be roughly estimated from ground surface topography if other sources of information are not available. In some instances both regional flow and base flow routes should be assessed to determine the controlling point of use.**
D	**Planning area density (population equivalents per acre)** **The risk of higher contaminates concentrations in the ground water from ground water-discharging treatment facilities will increase with increasing numbers of people served. Where building lots are served by individual infiltration systems, the population served divided by the total area composed by contiguous existing and planned lots would determine population equivalents per acre (p.e./acre). For a large cluster system, the p.e./acre would be determined by the population served divided by the area of the infiltration surface of the cluster system.**
E	**Well construction** **Wells developed in an unconfined aquifer with direct hydraulic connections to the wastewater discharge have a higher probability of impact than wells developed in a confined aquifer. Wells that are considered within the zone of influence from the wastewater discharge should be identified and their construction determined from well logs.**
F	**Travel time to base flow discharge, Tbf** **Treated wastewater discharges in ground water can affect surface waters through base flow. The potential impacts of base flows are inversely proportional to the travel time in the ground water, Tbf, because of the dispersion and dilution (except in karst areas) that will occur. Where aquifer characteristics necessary to estimate travel times are unknown, distance can be substituted as a measure. If travel time, Tbf, is greater than time to a ground water point of use, Ta, the ground water should be assumed to be the receiving environment.**
G	**Stream flow** **Stream flow will provide dilution of the wastewater discharges. The mixing and dilution provided are directly proportional to the stream flow. Stream flow could be based on the 7-day, 10-year low-flow condition (7Q10) as a worst case. “High” and “low” stream flow values would be defined by the ratio of the 7Q10 to the daily wastewater discharge. For example, ratios greater than 100:1 might be “high,” whereas those less than 100:1 might be “low.” Stream flow based on the watershed area might also be used (cfs/acre).**
H	**Travel time to aquifer or surface water point of use, Ta or Ts** **The potential impacts of wastewater discharges on points of use (wells, coastal embankments, recreational areas, etc.) are inversely proportional to the travel time. Except for coastal areas, distance could be used as a substitute for travel time if aquifer or stream characteristics necessary to estimate travel times are unknown.**
I	**Relative probability of impact** **The relative probability of impact is a qualitative estimate of expected impact from a wastewater discharge on a point of use. The risk posed by the impact will vary with the intended use of the water resource and the nature of contaminants.**

Adapted from : Otis, 1999.

1. Goals and Objectives

Protect the physical environment and enhance the character, quality and livability of the community by preserving the natural environment as an integral part of the development process.

Restore and improve natural resources

2. Objectives

- Identify natural and man-made features that have a significant influence on the environmental and aesthetic quality of the community.
- Provide open space within the community.
- Create a system of greenways and trails to link living areas, schools, shopping and other focal points as part of the open space network.
- Avoid the unnecessary destruction of environmentally sensitive areas such as streams, floodplains and areas with substantial vegetation.
- Encourage the conservation and protection of water resources, including the proper utilization of aquifer recharge areas to meet community needs.
- Maintain water quality to provide for the protection and propagation of wildlife and the enjoyment of water recreational activities.
- Plan development of watersheds in such a manner that the natural or existing drainage patterns and flood flow travel times are approximately duplicated.
- Encourage careful site planning and the use of construction techniques to minimize the adverse impact of noise, vibrations, fumes, and visual intrusions.
- Develop necessary new guidelines and public policies to encourage and promote harmonious development respecting the natural environment.
- Ensure safe waste management.

Ecologically sensitive area of the International Zone

Storm Water Management

A. Introduction

The purpose of this part of the study is to set up a general framework for a storm water management system in the International Zone (IZ) of Auroville. In it is an outline of some of the basic needs for an integrated, sustainable storm water management system (SWMS).

The City of Auroville receives significant amounts of rainfall in short periods of time, usually during the winter and summer monsoons. The rain cycle of this region will present unique challenges to the design of a storm water management system. The system must be designed to meet four basic requirements: to facilitate ground water recharge, reduce erosion, act as a flow-delaying device, and preferably assist in Irumbai Tank recharge. It must also be framed appropriately through landscaping techniques around buildings and infrastructure integration and beautification.

In our badly depleted groundwater situation, ground water recharge must be the primary focus of the SWMS. The system must make every effort to improve water recharge as infiltration rates in the IZ mainly are low. It has rates between 0.1-5 cm/hr, even 14 cm/hr in Kottakarai canyon. Further development will increase the impervious area, therefore increasing the runoff potential and finally reducing the groundwater recharge if not well integrated in the design phase. Properly managing this aspect of the system may ensure that as the population of the IZ grows to over 10,000 people per day there will be much ground water recharge. A large part of the International Zone is situated on a particular geological formation which seems to generate a slow subsurface water flow, finally ending in the Western part of the zone. By creating appropriate infiltration methods, the recharged water may be largely available in situ for further use.

- The system must also offer good control of soil erosion caused by storm runoff. Soil erosion control will help keep fertile soil in place. The fragile area surrounding the two canyons must be particularly looked at.
- The system must act as a flow time delay mechanism. Delaying the storm water flow is necessary for proper storm water management as it allows large flows of water to be handled efficiently and without risk of flooding. It also helps control erosion and limit surface water pollution by allowing particles to settle. The smooth and rather uniform topography of this area, apart from the low canyons and some secondary drains, will help to create appropriate storm water control easily, without disturbing the general pattern of the land.
- The western part of the IZ is mainly water logged, and is therefore problematic in terms of development and pollution risk. This must also be addressed.
- Irumbai Tank recharge is an important consideration due to the fact that local farmers depend on it for irrigation water. It is also foreseen as the main agricultural water supply of Auroville. However, tank recharge should be considered as a later goal, only to be met after ground water recharge, erosion and pollution controls are met.

B. Sustainability Principles for Urban Infrastructure

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

The following principles are suggested for sustainable infrastructure systems:

✓ 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 storm water 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.

- ✓ 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 storm water and using cisterns or other collection devices to capture and reuse storm water for lawn watering and toilet flushing.
- ✓ 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 storm water, assess charges based on the cost of providing storm water quality control for smaller storms and flood control for larger storms. Charges should be based on the imperviousness of the connected areas with higher charges being applied for directly connected areas, including 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.
- ✓ 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.
- ✓ Re-develop vacant or low-density development within currently developed areas at higher intensities.

- ✓ 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.
- ✓ Encourage telecommuting and the infrastructure necessary to make it work.
- ✓ 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.
- ✓ Develop a community designed for people first, that does not damage the natural environment, and enables a healthy and active lifestyle, where human interaction is an everyday event (Goldstein 1997).
- ✓ Housing, stores, and employment will be accessible (less than 20 minutes) to each other by walking, biking and transit (Goldstein 1997):
- ✓ 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%.*

C. Sustainability & 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:

- Large organizations are necessary to manage these systems.
- Large organizations with monopoly powers tend to be inefficient and less responsive to changing needs.
- Complex cost sharing arrangements need to be developed to fairly charge each group for its share of the cost of the system.

- 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).
- Large systems are inefficient if recycling of treated wastewater and storm water is desired, since it is necessary to pipe and pump this water back through the entire system.
- The failure of larger systems causes more serious consequences since larger areas are affected and illicit discharges are concentrated at fewer points.
- 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.
- 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.
- 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.
- 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.
- Once established, it is difficult to restructure large organizations that 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 its way in Auroville too. Perhaps, bigger is not better.

D. An Integrated, Sustainable System

It is recommended that the system to be developed meet the basic design requirements in a way that is highly integrated into the local environment. This means that the system manages the IZ's storm water needs in a way that is as localized as possible. Localizing the system has four main benefits.

The first among these is that a local system allows for greater growth flexibility as the IZ is expected to have an unpredictable growth rate. This flexibility is gained by the fact that whenever possible there is no hardened infrastructure to be put into place or altered. This means that existing management systems may be more easily upgraded or a new system can be easily put into place as needed. The lack of infrastructure brings up the second benefit of a localized system, lower costs due to reduced construction. Related to lower costs are faster completion rates, as designs should be kept as simple as possible. The fourth benefit of a localized SWMS is that it has a low profile in ecological terms. This means that the system should at the very least have no adverse affects on the local ecosystem and ideally should enhance the local ecosystem.

E. System Design

To ensure that the system meets its goals in a localized way, better design practices should be observed. The goals of better design practices are consistent with our desire for an integrated, sustainable SWMS in the International Zone. These design practices are outlined by the Georgia Storm Water Manual: To manage storm water as close to the point of origin as possible and to minimize collection and conveyance, preventing storm water impacts rather than mitigating them, to utilize simple, nonstructural methods that are lower in cost and maintenance than traditional structures, create a multidimensional landscape, and uses hydrology as a framework for site design[i].

In the context of the International Zone these better site design practices include preserving the natural features of the Zone, lowering the impact of the site design, reducing the amount of impervious cover, and utilizing the natural features of the area.

Preserving the IZ's natural features begins by conducting a thorough study of the geology and hydrology of the IZ so that a complete picture of how storm water functions on the land may be developed. Once storm water patterns are known it will then be possible to design a system that utilizes these patterns effectively. Preserving the natural features also includes preserving undisturbed natural areas and avoidance of building on areas that are prone to flooding or are ecologically sensitive.

Lowering the impact of site design includes fitting the design of the IZ and its SWMS to the terrain. This means that we want to work with the land and not against it. The IZ should be designed to take into account the fact that storm water either makes its way to Irumbai Tank, to areas of high infiltration rates such as the canyons, or to other natural drainage pathways. Designing systems to the land will greatly reduce the need for costly clearing and grading of the land and will also reduce the need for storm water management infrastructure.

Impervious cover should be kept to a minimum in the IZ. This is done by designing structures that are as large as necessary and as small as possible. Reducing the amount of impervious cover in the IZ will result in less storm water runoff to be managed, which means that management mechanisms can be smaller thereby reducing the need for infrastructure.

Finally, the SWMS in the IZ should not fail to effectively utilize the natural features of the land already present in the International Zone. This means that the development of the IZ should be sensitive to the natural drainage pathways of the land, which include the two canyons on the northern and southern boarders of the region as well as to areas of high infiltration rates. The system should be designed to protect and/or develop riparian buffers around these areas. Natural drainage pathways should be used to convey water to its natural destination rather than storm water sewers. Vegetated swales should be used instead of curbs and gutters.

If designed properly a localized, sustainable storm water management system will result in the successful local management of storm water without the need for the complicated, expensive, and inflexible infrastructure necessary to develop extensive structural storm water controls such as constructed ponds and wetlands, infiltration basins, sand filters, storm sewers, etc. These types of storm water control should only be considered after all other nonstructural storm water management options have been exhausted.

F. Better Site Design Practices

1. Overview

The first step in addressing storm water 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 storm water treatment. By implementing a combination of these nonstructural approaches collectively known as *storm water 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 storm water (quantity and quality) as close to the point of origin as possible and minimizing collection and conveyance
- Preventing storm water impacts rather than mitigating them
- Utilizing simple, nonstructural methods for storm water 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 storm water management includes a number of site design techniques such as preserving 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 storm water 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. Many of the better site design concepts can reduce the cost of infrastructure.

Reduction of adverse storm water runoff impact 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 storm water controls. The reduction in runoff and pollutants using better site design 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 storm water controls. In some cases, the use of better site design practices 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.

2. List of Storm water Better Site Design Practices and Techniques

1. Conservation of Natural Features and Resources

✓ Preserve Undisturbed Natural Areas	✓ Preserve Riparian Buffers
✓ Avoid Floodplains	✓ Avoid Steep Slopes
✓ Minimize Sitting on Porous or Erodible Soils	

2. 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	

3. 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 Storm water "Islands"

4. Utilization of Natural Features for Storm Water 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

3. Site Design Storm Water Credits

A set of storm water "credits" can be utilized by developers and site designers to implement better site design practices that can reduce the volume of storm water runoff and minimize the pollutant loads from a site. The credit system directly translates into cost savings to the developer by reducing the size of structural storm water control and conveyance facilities.

The basic idea of the credit system is to recognize the water quality benefits of certain site design practices by allowing for a reduction in the water quality treatment volume. If a developer incorporates one or more of the credited practices in the design of the site, the requirement for capture and treatment of the water quality volume will be reduced.

The better site design practices that provide storm water credits are listed in the table below. Site specific conditions will determine the applicability of each credit. For example, stream buffer credits cannot be taken on upland sites that do not contain perennial or intermittent streams. It should be noted that better site design practices and techniques that reduce the overall impervious area on a site already implicitly reduce the total amount of storm water runoff generated and are not further credited under this system.

Summary of Better Site Design Practices That Provide for Site Design Storm Water Credits

Practice	Description
Natural area conservation	Undisturbed natural areas are conserved on a site, thereby retaining their pre-development hydrologic and water quality characteristics.
Stream buffers	Storm water runoff is treated by directing sheet flow runoff through a naturally vegetated or forested buffer as overland flow.
Use of vegetated channels	Vegetated channels are used to provide storm water treatment.
Overland flow filtration/infiltration zones	Overland flow filtration/infiltration zones are incorporated into the site design to receive runoff from rooftops and other small impervious areas.
Environmentally sensitive large lot subdivisions	A group of site design techniques are applied to low and very low density residential development.

Site designers must be encouraged to utilize as many credits as they can on a site. Greater reductions in storm water storage volumes can be achieved when many credits are combined (e.g., disconnecting rooftops and protecting natural conservation areas). However, credits cannot be claimed twice for an identical area of the site (e.g. claiming credit for stream buffers and disconnecting rooftops over the same site area).

Due to local safety needs, soil conditions, and topography, some of these site design credits may be restricted.

1. Natural Area Conservation

A storm water credit can be taken when undisturbed natural areas are conserved on a site, thereby retaining their pre-developed hydrologic and water quality characteristics. Under this credit, a designer would be able to subtract conservation areas from total site area when computing water quality volume requirements. An added benefit will be that the post development peak discharges will be smaller, and hence water quantity control volumes (CP_v, Q_{p25}, and Q_f) will be reduced due to lower post-development curve numbers or rational formula "C" values.

Rule: Subtract conservation areas from total site area when computing water quality volume requirements.

Criteria:

- Conservation area cannot be disturbed during project construction
- It shall be protected by limits of disturbance clearly shown on all construction drawings
- It shall be located within an acceptable conservation easement instrument that ensures perpetual protection of the proposed area. The easement must clearly specify how the natural area vegetation shall be managed and boundaries will be marked [Note: managed turf (e.g., playgrounds, regularly maintained open areas) is not an acceptable form of vegetation management], and
- It shall have a minimum contiguous area requirement of 10,000 square feet
- R_v is kept constant when calculating WQ_v

2. Stream Buffers

This credit can be taken when storm water runoff is effectively treated by a stream buffer. Effective treatment constitutes treating runoff through overland flow in a naturally vegetated or forested buffer. Under the proposed credit, a designer would be able to subtract areas draining via overland flow to the buffer from total site area when computing water quality volume requirements. In addition, the volume of runoff draining to the buffer can be subtracted from the channel protection volume. The design of the stream buffer treatment system must use appropriate methods for conveying flows above the annual recurrence (1-yr storm) event.

Rule: Subtract draining areas via overland flow to the buffer from total site area when calculating water quality volume requirements.

Criteria:

- The minimum undisturbed buffer width shall be 50 feet
- The maximum contributing length shall be 150 feet for pervious surfaces and 75 feet for impervious surfaces
- The average contributing slope shall be 3% maximum unless a flow spreader is used
- Runoff shall enter the buffer as overland sheet flow. A flow spreader can be supplied to ensure this, or if average contributing slope criteria cannot be met
- Not applicable if overland flow filtration/groundwater recharge credit is already being taken
- Buffers shall remain unmanaged other than routine debris removal
- R_v is kept constant when calculating WQ_v

3. Vegetated Channels

This credit may be taken when vegetated (grass) channels are used for water quality treatment. Under the proposed credit, a designer would be able to subtract the areas draining to a grass channel from total site area when computing water quality volume requirements. A vegetated channel can fully meet the water quality volume requirements for certain kinds of low-density, residential development (see low impact development credit). An added benefit will be that the post-development peak discharges will likely be lower due to a longer time of concentration for the site.

This credit cannot be taken if grass channels are being used as a limited application, structural, storm water control technique towards meeting the 80% TSS removal goal for WQ_v treatment.

Rule: Subtract the areas draining to a grass channel from total site area when computing water quality volume requirements.

Criteria:

- The credit shall only be applied to moderate or low density residential land uses (3 dwelling units per acre maximum)
- The maximum flow velocity for storm water design quality shall be less than or equal to 1.0 feet per second
- The minimum residence time for the storm water quality shall be 5 minutes
- The bottom width shall be a maximum of 6 feet. If a larger channel is needed use of a compound cross section is required
- The side slopes shall be 3:1 (horizontal: vertical) or flatter
- The channel slope shall be 3 percent or less
- Rv is kept constant when calculating WQv

4. Overland Flow Filtration/Groundwater Recharge Zones

This credit can be taken when “overland flow filtration/infiltration zones” are incorporated into the site design to receive runoff from rooftops or other small impervious areas (e.g., driveways, small parking lots, etc). This can be achieved by grading the site to promote overland vegetative filtering or by providing infiltration or “rain garden” areas. If impervious areas are adequately disconnected, they can be deducted from total site area when computing the water quality volume requirements. An added benefit will be that the post-development peak discharges will likely be lower due to a longer time of concentration for the site.

Rule: If impervious areas are adequately disconnected, they can be deducted from total site area when computing the water quality volume requirements.

Criteria:

- Relatively permeable soils (hydrologic soil groups A and B) should be present
- Runoff shall not come from a designated hotspot
- The maximum contributing impervious flow path length shall be 75 feet
- Downspouts shall be at least 10 feet away from the nearest impervious surface to discourage “re-connections”
- The disconnection shall drain continuously through a vegetated channel, swale, or filter strip to the property line or structural storm water control
- The length of the “disconnection” shall be equal to or greater than the contributing length
- The entire vegetative “disconnection” shall be on a slope less than or equal to 3 percent
- The impervious surface area to any one discharge location shall not exceed 5,000 square feet

- For those areas draining directly to a buffer, either the overland flow filtration credit *-or-* the stream buffer credit can be used
- R_v is kept constant when calculating WQ_v

5. Environmentally Sensitive Large Lot Subdivisions

This credit can be taken when a group of environmental site design techniques are applied to low and very low density residential development (e.g., 1 dwelling unit per 2 acres or lower). The credit can eliminate the need for structural storm water controls to treat water quality volume requirements. This credit is targeted towards large lot subdivisions and will likely have limited application.

Rule: Targeted towards large lot subdivisions (e.g. 2 acre lots and greater). The requirement for structural practices to treat the water quality volume treatment requirements shall be waived.

Criteria:

For Single Lot Development:

- Total impervious site cover is less than 15%
- Lot size shall be at least two acres
- Rooftop runoff is disconnected in accordance with the criteria in Credit #4
- Grass channels are used to convey runoff versus curb and gutter

For Multiple Lots:

- Total impervious cover footprint shall be less than 15% of the area
- Lot areas should be at least 2 acres, unless clustering is implemented. Open space developments should have a minimum of 25% of the site protected as natural conservation areas and shall be at least a half-acre average individual lot size
- Grass channels should be used to convey runoff versus curb and gutter (see Credit #3)
- Overland flow filtration/infiltration zones should be established (see Credit #4)

G. Conclusion

In conclusion, designers and developers must utilize the better site design principles previously discussed in this paper in order to create an effective, localized storm water management system.

This system will be one that will manage ground water recharge, erosion control, flow delay, and Irumbai recharge in a localized manner. By conserving the natural features of the land, using low impact design techniques, reducing impervious cover, and utilizing appropriate landscaping, the storm water management system will be able to meet its design requirements while remaining flexible in its ability to grow along with the needs of the community.

The particular geological setup of the International Zone may allow for water extraction from sub-surface flow. Hence, to ensure maximum recharge of the entire area it should create a suitable supply of the same.

A storm water management system designed and implemented using better design techniques will set an example of sustainability in storm water management, not only for Auroville, but for the rest of the world as well.

However, to begin with, further study must now be done of the geology and hydrology of the area.

Due to the site impact and further considerations around canyon protection, large landscaping programs should be launched without further delay, in order to create appropriate conditions for further growth of the zone.

Landscaping

A. Purpose

The goal of this section is to provide various landscaping techniques that work with the land, utilizing natural aspects such as drainages, contours and geological formations to establish a system which contributes to the quantity and quality of the surface water retained. The main effort here is to provide aesthetic beauty in the zone, and at the same time to fulfill the practical needs of appropriate storm water management. If these methods are applied correctly, they should be able to minimize pollution risks, promote percolation and infiltration of rainwater, slow runoff, and decrease evaporation while also maintaining a level of visual beauty, reducing the needs for extensive development and infrastructure. These techniques would ideally utilize plants that are native or appropriate to the given climatic conditions, promoting low water and maintenance.

B. Introduction

All the physical aspects mentioned affect how the recharge devices work and also their effectiveness on the actual landscape. Due to the large amount of fluctuation in the infiltration rate, the runoff rate in the zone and its large drainage devices, there is the potential for soil erosion and siltation if not properly landscaped and developed.

The International Zone is planned to be the sight of numerous pavilions and will be the sight for all of the tourists to visit and spend time.

It is estimated to have 3,000 permanent residents and 7,000 guests and workers at any given time.[6] This is a vast increase in the population of the zone. Because of this and the fact that the International Zone is located on a rather significant section of land with the above-mentioned geological layout, it is very important that the development of this land be done in a manner which provides for the protection of these fragile and important aspects. The landscaping can make a huge impact on how much water is collected and infiltrated into the land as well as the quality of that water. It can be designed to prevent runoff, slow the velocity of the water helping to decrease erosion, and it can decrease siltation and pollution of the large drainage systems that are in place, preserving their capacities. At the same time it can be designed in an aesthetically pleasing manner.

Appropriate landscaping techniques could be applied to the development of this zone, not only greatly impacting the quality and quantity of ground and surface water but also the visual and atmospheric pleasantness of the area.

Native plant species or those adapted to the climate can provide many benefits to this zone. These plants can provide higher amounts of percolation, improve the soil quality, stabilize embankments that prevent erosion, decrease temperatures, humidity and evaporation rates, and can also help to cleanse the runoff providing even greater protection, while requiring the least amount of water and other needs.[7]

Buffer zones utilizing these native species could be created to protect the large drainage devices. In the majority of the International Zone it will not be appropriate to have dense vegetation. Medium and large trees with fairly large canopies would be highly beneficial for producing the needed amounts of shade, combined with gentle and disseminated intermediate vegetation, while grassing should be regulated as much as possible, due to its tremendous effect on infiltration. The limitation of dense vegetation will provide for greater air circulation, which decreases humidity. In other sections like the area surrounding the canyons the need for multi-stage vegetation with a combination of various types of ground cover and smaller types of vegetation may be appropriate in order to fulfill a particular local need (erosion and pollution control for example).

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[6] Helmut, 2002. *The International Zone of Auroville*

[7] Metropolitan Council – Environmental Services, 2003, Urban *Small Sights Best Management Practices.* Accessed via the internet at: www.metrocouncil.org/environment/watershed/BMP/manual.htm.

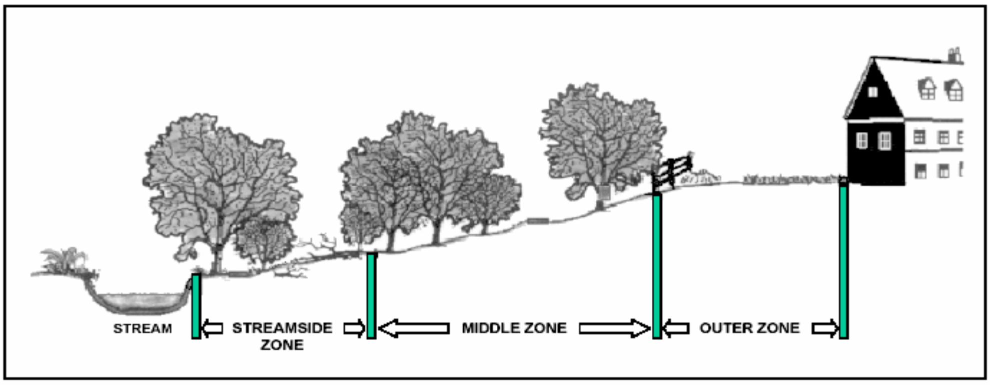
Elsewhere, locally dense vegetation may help generate a wind tunnel effect, facilitated by the natural topography, or create protective area where nuisances are expected. However, this would probably only be for limited areas.

These techniques would greatly benefit the recharge of the already receding aquifers. Possibly, over time, through these techniques as well as other practices Auroville could make a positive impact on the water situation and increase the overall health of the land.

C. Reasons Behind The Techniques

As previously mentioned, in the future many more people will be visiting this zone and a large amount of development will take place in the form of roads and building structures. This will greatly increase the amount of impervious surface within this zone. It is therefore necessary that the landscape be created so that it can collect, slow and cleanse the runoff in a manner that also does not impact the natural geological features of the existing zone. Due to these constraints the particularity of the soil and of the geological layout of this area must be taken into account, and designed appropriately to the needs.

Buffer zones are a good method for protecting the integrity of large natural drains and ponds. Buffer zones are fairly easy to implement and usually consist of trees and other vegetation, typically outlying a sensitive area like a catchment pond, canyon, etc. Usually they have a series of layers consisting of fairly dense vegetation in the nearest stretch, a middle region of much less dense vegetation that incorporates more ground cover and smaller plant species and a further layer which is generally grassy with a few trees to provide some shade.



Typically, the first part is starting with the 100-year flood plain line and extending about 10 meters around the area in question. This is followed by another layer that would consist of less dense forest and other forms of vegetation, which act to clean the runoff and also to provide protection in the form of velocity controls and energy dissipation to the drain in which the water is flowing. A third layer usually exists which acts as a preliminary device to slow the water and to do simple cleansing of silt and larger solids leading to the edge of a developmental area. It should be noted that this technique has the ability to incorporate bike paths and walking trails and, in its outreach, playing fields and other recreational outlets.

Suggested Riparian Buffer Management Zones			
	Streamside Zone	**Middle Zone**	**Outer Zone**
Width	Minimum 10 meters plus wetlands and critical habitat	Variable depending on stream order, slope, and 100-year floodplain (min. 8 meters)	8 meters minimum setback from structures
Vegetative Target	Undisturbed mature forest. Reforest if necessary.	Managed forest, some clearing allowed.	Forest encouraged, but usually turf grass.
Allowable Uses	**Very Restricted**	**Restricted**	**Unrestricted**
	e.g., flood control, utility easements, footpaths	e.g., some recreational uses, some storm water controls, bike paths	e.g., residential uses including lawn, garden, most storm water controls

The idea of a buffer zone between roadways and other forms of impervious surfaces is that the runoff generated by the less permeable surfaces, will be adequately cleansed, removing much of the silt and solid forms of waste, and slowed to the point where it will not negatively impact the existing drains and catchment systems.

Swales are created and strategically placed next to potentially high runoff areas, such as areas bordering roads and parking areas. They are grassy strips of land that can range in size from 3 to 10 meters or more depending on the needs of the situation. These are usually created where there is not enough room for increased landscaping techniques.

Swale in the International Zone

They act to remove solid forms of waste, cleaning the water and also slowing its flow. These structures tend to be slightly indented allowing for limited drainage capabilities. They also provide ground cover, preventing erosion and influencing energy dissipation.

Bund

Other forms of control exist to slow the speed of runoff and also to divert its flow so as to increase infiltration into more appropriate areas.

Bunds placed over roadways and other less permeable places can act to slow and retain water, and also to direct its flow into a more forested or vegetated area where the infiltration is higher.

Ponds can act not only as large drainage devices, but also as places to clean water and runoff that may not be at optimum levels, returning it to safe conditions for irrigation or infiltration.[8]

Pond in Alankuppam

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[8] Georgia Storm water Management Manual Volume 2, 2001.

Certain types of plants can be used to increase the removal of pollutants, and buffers can provide shade, stability to the physical structures that hold and store runoff, stabilize the soil and increase percolation and infiltration, and minimize evaporation and vapor-transpiration. Many of these plants are characteristic of the traditional vegetation that once covered the landscape, which are among the best suited for the area in the sense that they will be the most likely to survive and flourish in the given region, under the given constraints and water availability.

All of these devices act in synergy to promote a healthy natural system. If done properly, these techniques could become a major component of storm water management and have a large impact on the quality and quantity of ground water retained by reducing the need for infrastructure, development costs and maintenance.

D. Applications of Landscaping Techniques

The population of this area will be dramatically increasing; therefore, if the correct types of preventative measures are not incorporated into the landscaping plans soon, large complex problems could develop. The above techniques can be applied to all aspects of building and development to maximize the amount of infiltration, catchment, utility, and aesthetic beauty. Buildings should be built taking into consideration that the increased impermeable surfaces means increased runoff that has to be dealt with.

As a result bunding, ponds, and swales should be developed to maximize the amount of water catchment and recycling. Ponds can be developed in areas as both a wastewater control device, and as a system to deal with the runoff of a given section. They can be developed to cleanse the wastewater and runoff before it is infiltrated, or used for irrigation. Bunds and swales can be adapted to this need as well, acting as devices for directing the flow of the water into appropriate areas. Swales can be applied to areas outlying a building, etc, to increase infiltration, do simple cleansing and catchment of runoff, and they can act as a natural way of directing this water into appropriate areas.

To maintain the integrity of the zone and its water quality there should be no development occurring in areas that are considered to be sensitive, or near important drainage devices. It is commonly thought that land with vegetation in the form of trees, gardens and other forms of landscaping tend to be held in higher esteem as far as aesthetic beauty and land value. It is recommended, as far as replanting and gardening and other types of natural development of the zone, that these techniques be applied around building structures, walkways and roads. This can provide cooler temperatures, decreased rates of evaporation and runoff, but also a sense of nature and beauty that is otherwise lost in the nearly barren landscape that exists now. The underlying idea is that the development that occurs should not damage or affect the existing geological formations and other sensitive areas of the zone or promote negative environmental consequences and increased amounts of runoff or pollution.[9]

When dealing with an area that is being designed to handle a large amount of people, and visitors it is always important to design it in such a way as to allow for open space. This concept provides a space that people can use for recreational activities, leisure, relaxation, and countless other possibilities. Open-space should also be taken into consideration to allow for greater aesthetic beauty, but it should not be densely forested or replanted in a manner that impedes the likelihood of it being used. These areas should be landscaped in a manner where the runoff can be collected or directed into either a catchment facility, a natural drain or into a vegetated area that will provide for the necessary amount of infiltration needed. These areas should also provide such things as paths and clearings that promote its usage as opposed to more sensitive areas like natural drains and catchment ponds, which require more protection. This acts to promote wildlife and allow nature to flourish while at the same time providing for the benefit of the people using it.

When gardens are being planned they should be done so in a fashion that minimizes the amount of water needed. Xeriscape gardening techniques can be applied to any part of the zone. This style of gardening entails creating beautiful and lush gardens with vegetation that requires very little water. In order to properly figure out what paths should be taken at a certain site such factors such as soil quality, existing vegetation, topography, irrigation needs, and the style of plants that are desired must be taken into consideration. This type of gardening tends to be more pleasant

[9] Metropolitan Council – Environmental Services, 2003, *Urban Small Sights Best Management Practices.* Accessed via the internet at: www.metrocouncil.org/environment/watershed/BMP/manual.htm

and aesthetically pleasing than zero-scape gardening which consists of using rocks and other types of extremely dry environment plants like cactus and simple trees, suited to promote a hotter less comforting feeling.[10]

Kottakarai village is a unique aspect of this zone because it is a village that, in the future, will lie completely within the International Zone. It is much more densely developed with many buildings, paved roads and a simple infrastructure mainly for water and electricity needs. It has open gutters on the sides of the roads which catch all of the runoff, and waste water during times when there is no rainfall.

It is also proposed to be the sight of service based industries for the International Zone in the future. Due to these constraints, landscaping should be done to minimize the impact of the village on the larger water shed system at hand.

Open Sewage in Kottakarai Village

The villages tend to be more developed in terms of roads and infrastructure, which also attracts higher amounts of traffic and waste in the form of water. This, combined with inadequate sanitation and waste management negatively impacts the land. The runoff experienced in these areas could be routed into wetland type areas or ponds, which can handle the amount of wastewater generated. These devices can then be landscaped with the correct plants to remove the more hazardous substances and return the water to a usable state, adequate for irrigation or infiltration into the ground.

E. Plant Possibilities

During the design of the International Zone, appropriate types of plants will need to be considered. Since this zone is rather undeveloped and its future plan is to become

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10 *City of Albuquerque – Public Works Water Conservation Office, 2004. The Advantages of Xeriscaping. Accessed via the internet at: www.cabq.gov/waterconservation/xeric.html.*

the sight of tourism where the visitors of Auroville will spend their time, it will need to be developed in a manner that appropriately deals with this problem. The landscape as it exists now is fairly barren.

F. Urban Agriculture and roof gardening?

One of the trends of sustainable development of particular relevance for urbanized areas is spreading around earth under the name of Urban Agriculture. The idea is that part of the vegetables and fruits for the urban population are grown within the city itself. The most beautifully integrated town on this model is Havana, Cuba, where due to economic embargo the population has to develop means to generate food out of limited energy and fertilizer resources. SIXTY per cent of the vegetables consumed in Cuba today are organically grown in city gardens.

Another interesting concept is roof gardening. This technique is helping in many ways, by regulating the temperature in the buildings, creating a highly integrated visual development, and generating greenery and food out of otherwise useless surface. The possibility to recycle grey water directly for roof gardening is appealing as well.

G. Conclusions

Due to the constraints of the zone and the underlying goal for aesthetic beauty, the landscaping techniques applied must be done in a value-oriented fashion. There will be different needs within each pavilion. As such, it will not be appropriate to recommend that the entire zone be landscaped in the same way. However, the different ways of landscaping should work with each other so that the overall layout is cohesive. For example, when implementing a swale all landscaping techniques in its area must work with it.

It is strongly recommended that buffer zones be utilized surrounding the natural drains of the zone. They are of the utmost importance as ground water recharge devices and should be protected as mush as possible. When implementing these zones it is recommended to follow a design with multiple layers of vegetation ranging from the most dense section bordering the water body or drain to a rather open area that has a healthy ground cover with only a few trees for shade purposes.

Native or adapted plants should be used since they are the most likely to survive and flourish in the given conditions, and many of them would minimize the amount of water needed.

Swales are highly recommended for the simple cleansing of runoff, energy dissipation, erosion controls, and diverting water flows. These structures can, if designed properly, cleanse runoff by removing larger solids and silt, and help slow water, thereby helping to prevent erosion. Swales should be incorporated into the development of the zone's outlying areas with high amounts of impermeable land, like roadways, but they should not be placed in areas where it will cause problems for traffic or pedestrians. They should be planted mainly with ground cover, but should also have some trees planted on their embankments to provide shade, reducing the amount of evaporation.

Bunds are effective at diverting water and helping prevent runoff. However, in this zone they should be utilized in a fashion where they do not hinder recreational activities near the pavilions. They should need to be used only on roadways where the amount of impermeable surface promotes runoff. These devices act as safety measures as far as controlling the speed of traffic, but can also direct water into ponds or vegetated areas where the runoff can be more efficiently contained.

Ponds are great tools for the catchment and storage of rainwater, but can also be designed as water-cleansing devices. These structures can take the form of wetlands if being used to collect wastewater or runoff and can effectively remove pollutants, making the water suitable for irrigation or ground water recharge. This can be integrated around Kottakarai to collect and clean the water that is generated in the open sewer system that now exists. Otherwise, ponds can be developed to effectively store rainwater for future use and enhance the recharge of ground water.

These structures should have some sort of a buffer zone surrounding them, which will assist in the removal of trash and silt. Trees should have large canopies to decrease the amount of direct sunlight over the majority of the pond.

Gardening will need to be considered in a value-oriented manner. The style of gardens will reflect the needs of each pavilion. The underlying idea here is that xeriscape ideals should be considered. That means using plants that are suited to the climactic conditions, requiring the least amount of water and maintenance. These gardens should have a plethora of species which act together to produce a beautiful urban space. It is considered more attractive to have lush flowery gardens as apposed to more dry and hot styles of garden.

Rainwater Harvesting

Catch the water where it drops

A. Using Rainwater

Rainwater Harvesting (RWH) is the well planned collection and storage of rain water that runs off a natural or man-made catchment surface. This is an ancient technique and can be found in all great civilizations. In order to meet the goals of collection and storage, there is a wide range of applied technologies which can be as simple or as sophisticated as required.

Rainwater harvesting has become tremendously interesting to academics, institutions, media and lay people, especially in the past few years, all over India. While rainwater harvesting is broadly described in the rural context as water collected mainly for agriculture purposes in dry land and tank irrigated areas, rooftop rainwater harvesting has a narrower definition as water collected from rooftops chiefly for domestic consumption.

People have relied on rainwater for household, landscape and agricultural water usage for centuries. As communities have become larger and more centralized, community water treatment and distribution systems have gradually replaced the collection of rainwater as our primary water supply. Recently, there has been a renewed interest in collecting and storing rainwater for non-drinking purposes such as toilet, laundry and garden use. Why? Because a typical house roof and 200 liters of tank storage can provide up to a half of the average toilet water use. And rainwater needs little or no treatment for non-drinking, household purposes.

1. A Brief Introduction to Rainwater Harvesting

A good quality Rainwater Harvesting (RWH) system provides people with access to an on-site water supply, either next to their homes or at local public buildings such as schools and health centers. Rainwater has been collected and used for drinking water for centuries, but in recent years the technique has fallen out of favor as it is considered old-fashioned. Ideally, the RWH collection system should involve basic construction techniques, be inexpensive to maintain, and have a long functional life span (Pacey 1986).

If the system is designed well, it should provide a good safe source of drinking water at a relatively low cost when compared to the main supply.

The RWH system provides a good alternative water supply option, especially for areas where the following characteristics apply:

- Alternate sources of water do not provide sufficient quantities of potable water
- The available sources of water are of a poor quality, so that the construction and maintenance of expensive treatment plants would be prohibitive,
- The rainwater catchment area per capita, i.e. roofs, tends to be large
- It operates independently, and therefore gives people access to water without their being dependent on a grid supply which can be unreliable,
- The cost of supplying grid water is too high,
- Pollution levels tend to be low when compared to average towns and cities, making the water more suitable for consumption without treatment.

2. Why harvest rainwater?

Rainwater harvesting has an important role to play as one of several options available on a demand-responsive basis, as it offers a relatively cheap and interesting way of giving an additional supply above a basic service level. It can of course, in some cases, also be the main supply in its own right.

- ✓ **Save water!** Reduce the demands on scarce surface and ground water sources. Reuse water instead of pulling from the water table (or a freshwater source): in comparison, centralized water systems and wells pull from the water table.

Increase infiltration of rainwater in the subsoil, especially useful in urban areas where saving water has decreased dramatically due to the presence of large, impervious areas.

- ✓ **Reduce erosion and storm water run-off and increase water quality!** Capturing the rain reduces flash floods and storm water runoff. Less storm water run-off may reduce the need for storm water collection networks at the individual household level, as well as at a more complex, collective level, and will certainly improve the health, quality, and biodiversity of our watersheds, as well as replenish the water table (or our freshwater supply).

- ✓ **Save energy!** By reducing water use, energy demands to pump water from groundwater or other sources are reduced. The dependency on polluting power plants will also decrease as a result of collecting rainwater.

- ✓ **Save money**! Avoid the increasing economic and environmental costs associated with a centralized water system. It localizes the process of water collection, which results in a reduction of the amount of civil engineering work associated with a grid connection. Operating costs are lower than the cost of purchasing water from the centralized water system.

- ✓ **And also…**

  - Saves a natural resource presently wasted
  - Prevents ground water depletion
  - Provides a good supplement to piped water
  - Secures a positive cost benefit ratio
  - Is relatively pollution-free
  - Supports water conservation & self-dependence
  - Promotes the reduction of an “ecological footprint”

3. WHO can harvest Rainwater ???

- Rural and urban Industries & Institutions
- Buildings
- Paved & Unpaved land for Ground water-recharge and surface collection

B. The Law

Through an ordinance titled *"Tamil Nadu Municipal Laws ordinance, 2003"*, dated July 19, 2003, the government of Tamil Nadu has made rainwater harvesting mandatory for all buildings, both public and private, in the state. The deadline to construct rainwater harvesting structures was August 31, 2003.

The ordinance cautions, "Where the rain water harvesting structure is not provided as required, the Commissioner or any person authorized by him in his behalf may, after giving notice to the owner or occupier of the building, cause rain water harvesting structure to be provided in such building and recover the cost of such provision along with the incidental expense thereof in the same manner as property tax". It also warns the citizens they may be penalized by the disconnection of their water supply if rainwater harvesting structures are not provided.

CHENNAI, SATURDAY, JULY 19, 2003

TAMIL NADU ORDINANCE No.4 OF 2003

An Ordinance further to amend the Laws relating to the Municipal Corporations and Municipalities in the State of Tamil Nadu.

(i) PART-III

AMENDMENT TO THE TAMIL NADU DISTRICT MUNICIPALITIES ACT, 1920.

Tamil Nadu Act V of 1920. 3. After section 215 of the Tamil Nadu District Municipalities Act, 1920, the following section shall be inserted, namely: Insertion of new section 215-A.

"215-A Provision of Rain Water Harvesting Structure.- (1) In every building owned or occupied by the Government or a statutory body or a company or an institution owned or controlled by the Government, rain water harvesting structure shall be provided by the Government or by such statutory body or company or other institution, as the case may be, in such manner and within such time as may be prescribed.

(2) Subject to the provisions of sub-section (1), every owner or occupier of a building shall provide rain water harvesting structure in the building in such manner and within such period as may be prescribed.

Explanation.- Where a building is owned or occupied by more than one person, every such person shall be liable under this sub-section.

(3) Where the rain water harvesting structure is not provided as required under sub-section (2), the Executive Authority or any person authorised by him in this behalf may, after giving notice to the owner or occupier of the building, cause rain water harvesting structure to be provided in such building and recover the cost of such provision along with the incidental expense thereof in the same manner as property tax.

(4) Notwithstanding any action taken under sub-section (3), where the owner or occupier of the building fails to provide the rain water harvesting structure in the building before the date as may be prescribed, the water supply connection provided to such building shall be disconnected till rain water harvesting structure is provided.

EXPLANATORY STATEMENT

In order to augment ground water resources, it has been decided to make it mandatory to provide rain water harvesting structure in all building. As rain water harvesting structures will have to be put up before the ensuing monsoon, it has also been proposed to give a time limit to be specified in the Rules, to provide rain water harvesting structure by the owner or occupier of every building and in case they do not provide rain water harvesting structure within the above said period, the authorities of the local body concerned will provide the rain water harvesting structure in those buildings and recover the cost of provision of rain water harvesting structure with the incidental expense from such owner or occupier as property tax.

2. It has also been decided that if such owner or occupier of the building fails to provide rain water harvesting structure on or before the date to be specified in the Rules, the water supply connection provided to such building shall be disconnected.

3. The Ordinance seeks to give effect to the above decisions

CHENNAI, MONDAY, JULY 21, 2003

Tamil Nadu Acts and Ordinances.

TAMIL NADU ORDINANCE No.4 OF 2003

An Ordinance further to amend the Tamil Nadu Panchayats Act, 1994.

"257-A Provision of Rain Water Harvesting Structure.- (1) In every building owned or occupied by the Government or a statutory body or a company or an

(1) institution owned or controlled by the Government, rain water harvesting structure shall be provided by the Government or by such statutory body or company or other institution, as the case may be, in such manner and within such time as may be prescribed

(2) Subject to the provisions of sub-section (1), every owner or occupier of a building shall provide rain water harvesting structure in the building in such manner and within such period as may be prescribed.

Explanation.- Where a building is owned or occupied by more than one person, every such person shall be liable under this sub-section.

(3) Where the rain water harvesting structure is not provided as required under sub-section (2), the Executive Authority or any person authorised by him in this behalf may, after giving notice to the owner or occupier of the building, cause rain water harvesting structure to be provided in such building and recover the cost of such provision along with the incidental expense thereof in the same manner as property tax.

(4) Notwithstanding any action taken under sub-section (3), where the owner or occupier of the building fails to provide the rain water harvesting structure in the building before the date as may be prescribed, the water supply connection provided to such building shall be disconnected till rain water harvesting structure is provided.".

It is with this strong statement that the Directorate of Town Panchayats launched its campaign of Water Harvesting in Tamil Nadu.

C. Rainwater quality

Rainwater gets its composition largely by dissolving particulate materials in the atmosphere and secondarily by dissolving gasses from the atmosphere.

Rain composition varies significantly from place to place because the regional geology can greatly affect the types of particulates that get added to the atmosphere. Particulate load to the atmosphere can also be greatly affected by human activities.

However, in general, the quality of rainwater is very good. The softness of rainwater is valued for its cleaning abilities and benign effects on water-using equipment.

Although rainwater collected from roof catchments has been regarded as a source of safe water for drinking purposes, studies have shown that its quality is affected when the roof is contaminated by diffuse sources of pollution from the atmosphere and with the feces of birds and other creatures, as well as from deterioration of the roofing material itself.

D. Rainwater Harvesting to Augment Groundwater Resources

Rainwater Harvesting is the technique of collecting and storing rain water at the surface or in sub-surface aquifers, before it is lost as surface run-off. The augmented resource can be harvested in time of need. Artificial recharge to ground water is the process by which the ground water reservoir is augmented at a rate exceeding the natural conditions of replenishment.

1. Advantages

- The cost of recharge to the sub-surface reservoir is lower than to the surface reservoirs.
- The water table serves as a distribution system also.
- Ground water is not directly exposed to evaporation and pollution.
- It increases the productivity of the aquifer and raises ground water levels.
- Reduces flood hazards.
- Reduces soil erosion.

2. Design considerations

The important aspects to be looked at for designing a rainwater harvesting system to augment ground water resources are:

- ✓ Hydrogeology of the area including the nature and extent of the aquifer, soil cover, topography, depth to water level and the chemical quality of ground water.
- ✓ The availability of source water, one of the prime requisites for ground water recharge, basically assessed in terms of non-committed, surplus, monsoon runoff.
- ✓ Area contributing runoff like area available, land use pattern, industrial area, residential area, green belt, paved areas, roof top area, etc.
- ✓ Hydro-meteorological characteristics like rainfall duration, general pattern and intensity of rainfall.

3. Potential Areas

- ✓ Where groundwater level is declining on regular basis.
- ✓ Where substantial amounts of the aquifer are unsaturated.
- ✓ Where availability of groundwater is inadequate.
- ✓ Where due to rapid urbanization, infiltration of rainwater into the subsoil has decreased drastically and the recharging of the ground water has diminished.

6. Urban areas

In urban areas, rainwater available from the roof tops of buildings, paved and unpaved areas goes to waste. This water can be recharged to the aquifer and can be well utilized in time of need. The rainwater harvesting system needs to be designed so that it does not occupy a large space for collection and recharge system. A few techniques of roof top rain water harvesting in urban areas are described below.

7. Rural areas

In rural areas, rainwater harvesting is taken up using the watershed as a unit. Surface spreading techniques are common since space for such systems is available in plenty and there is a large amount of recharged water. The following techniques may be adopted to save water going to waste from slopes, rivers, rivulets and nalas.

By looking at the general concept for Auroville's International Zone, it is very clear that all of the available techniques should be investigated and evaluated according to the site conditions.

4. METHODS & TECHNIQUES

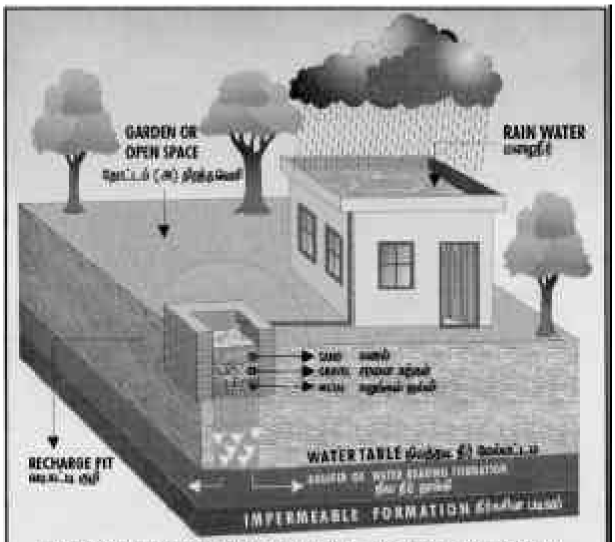
The methods of ground water recharge are mainly:

1. Recharge Pit	2. Recharge Trench
3. Tubewell	4. Recharge Well
5. Gully Plug	6. Contour Bund
7. Gabion Structure	8. Percolation tank
9. Check Dam / Cement plug / Nala Bund	10. Recharge shaft
11. Dugwell Recharge	12. Groundwater Dams / Subsurface Dyke

1. ROOFTOP RAINWATER HARVESTING THROUGH A RECHARGE PIT

In alluvial areas where permeable rocks are exposed on the surface or at very shallow depths, roof top, rain water harvesting can be done through recharge pits.

- ✓ It is suitable for buildings having a roof area of 100 m2. They are constructed for recharging the shallow aquifers.
- ✓ Recharge Pits may be of any shape and size and are generally constructed 1 to 2 m wide and 2 to 3m deep which are backfilled with boulders (10-20 mm), gravel (5-10mm) and coarse sand (1 .5-2 mm) in graded form- Boulders at the bottom, gravel in between and coarse sand at the top, so that the silt content that will come with runoff will be deposited on the top of the coarse sand layer and can easily be removed. For smaller roof areas, a pit may be filled with broken bricks/cobblestone.

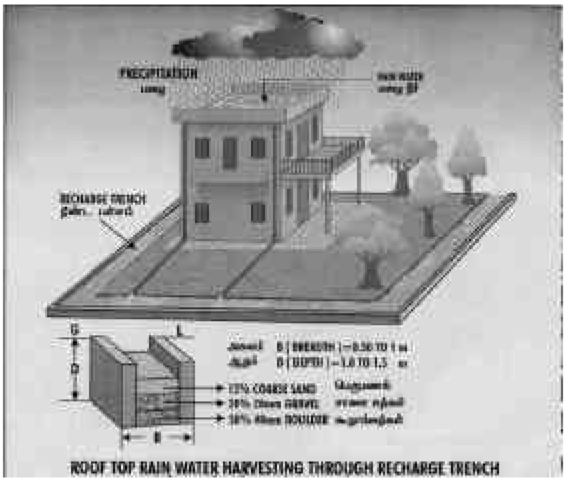


ROOF TOP RAIN WATER HARVESTING THROUGH RECHARGE PIT

- ✓ A mesh should be provided on the roof so that leaves or any other solid waste/ debris is prevented from entering the pit and a desilting/collection chamber may also be provided at ground level to arrest the flow of finer particles to the recharge pit.
- ✓ The top layer of sand should be cleaned periodically to maintain the recharge rate.
- ✓ A by-pass arrangement must be provided in front of the collection chamber to reject the first flow of water.

2. ROOFTOP RAINWATER HARVESTING THROUGH A RECHARGE TRENCH

Recharge trenches are suitable for buildings having a roof area of 200-300m2 and where permeable strata are available at shallow depths.



ROOF TOP RAIN WATER HARVESTING THROUGH RECHARGE TRENCH

- ✓ A trench may be 0.5-1 m wide, 1-1.15 m deep and 10-20m long depending upon the availability of water to be recharged.
- ✓ These are backfilled with boulders (10-20 mm), gravel (5-10 mm) and coarse sand (1.5-2 mm) in graded form - boulders al the bottom, gravel in between and coarse sand at the top so that the silt content that will come with runoff will be deposited on the top of the sand layer and can easily be removed.
- ✓ A mesh should be provided at the roof so that leaves or any other solid waste/debris is prevented from entering the pit and a desilting/collection chamber may also be provided on the ground to arrest the flow of finer particles to the recharge pit.
- ✓ A by-pass arrangement must be provided before the collection chamber to reject the first flow of water.
- ✓ The top layer of sand should be cleaned periodically to maintain the recharge rate.

3. ROOFTOP RAINWATER HARVESTING THROUGH EXISTING TUBE WELLS

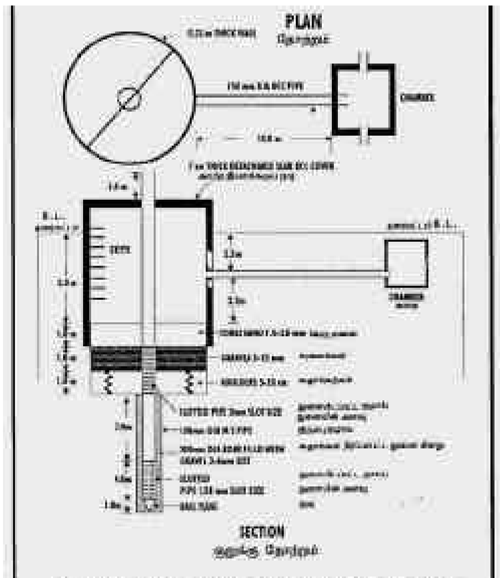
ROOF TOP RAIN WATER HARVESTING THROUGH EXISTING TUBEWELLS

- ✓ In areas where the shallow aquifers have dried up and existing tube wells are tapping deeper aquifers, rooftop, rain water harvesting through existing tube wells can be adopted to recharge the deeper aquifers.

- ✓ PVC pipes of 10cm dia. are connected to roof drains to collect rain water. The first roof runoff is expelled through the bottom of the drain pipe. After closing the bottom pipe, the rain water of subsequent rain showers is taken through a T to an online PVC filter. The filter may be provided before water enters the tube well. The filter is 1-1.2m in length and is made up of PVC pipe. Its diameter should vary depending on the roof area, 15 cm if roof area is less than 150m2 and 20cm if the roof area is more. The filter is provided with a reducer of 6.25cm on both sides. The filter is divided into three chambers by PVC screens so that filtered material is not mixed together. The first chamber is filled with gravel (6-10mm), the middle chamber with pebbles (12-20mm) and the last chamber with bigger pebbles (20-40mm).
- ✓ If the roof area is larger, a filter pit may be provided. Rain water from roofs is taken to collection/desilting chambers located on the ground. These collection chambers are interconnected as well as connected to the filter pit through pipes having a slope of 1:15. The filter pit may vary in shape and size depending upon available runoff and are back-filled with graded material, boulders at the bottom, gravel in the middle and sand at the top with varying thickness (0.30-0.50m) and may be separated by a screen. The pit is divided into two chambers, filter material in one chamber, while the other chamber is kept empty to accommodate excess filtered water and to monitor the quality of filtered water. A connecting pipe with a recharge well is provided at the bottom of the pit for the recharging of filtered water through the well.

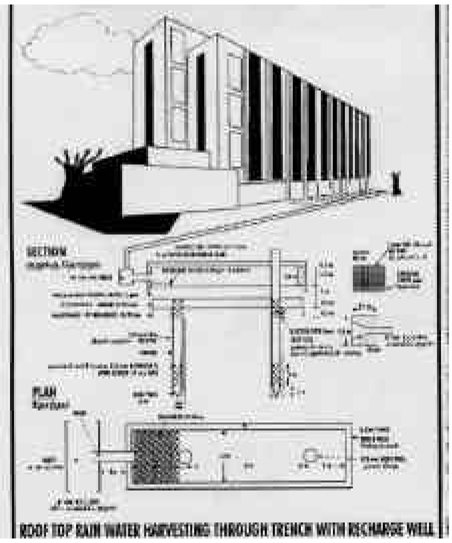
4. ROOF TOP RAINWATER HARVESTING THROUGH A TRENCH WITH A RECHARGE WELL

In areas where the surface soil is impervious and large quantities of roof water or surface runoff is available within a very short period of heavy rainfall, trench/pits are used to store the water in a filter media and subsequently recharge to groundwater through specially constructed recharge wells.



RAIN WATER HARVESTING THROUGH RECHARGE WELL

- ✓ This technique is ideally suited for areas where the permeable level is within 3m below ground level.
- ✓ A recharge well of 100-300 diameters is constructed to a depth of at least 3 to 5m below the water level. Based on the lithology of the area, well assembly is designed with a slotted pipe against the shallow and deeper aquifer.
- ✓ A lateral trench of 1.5-3m width and 10-30m length, (depending upon the availability of water) is constructed with the recharge well in the centre.
- ✓ The number of recharge wells in the trench can be decided on the basis of water availability and local, vertical permeability of the rocks.
- ✓ The trench is backfilled with boulders, gravel and coarse sand to act as a filter media for the recharge wells.



ROOF TOP RAIN WATER HARVESTING THROUGH TRENCH WITH RECHARGE WELL

- ✓ If the aquifer is available at a greater depth -- say more than 20m, a shallow shaft of 2 to 5 m diameters and 3-5 meters deep may be constructed depending upon the availability of runoff. Inside the shaft a recharge well of 100-300mm dia is constructed for recharging the available water to the deeper aquifers. At the bottom of the shaft a filter media is provided to avoid choking the recharge well.

5. RAINWATER HARVESTINGTHROUGH A GULLY PLUG

Gully Plugs are built using local stones, clay and bushes across small gullies and streams running down the hill slopes carrying drainage to tiny catchments during the rainy season.

RAIN WATER HARVESTING THROUGH GULLY PLUG

- ✓ Gully Plugs help in conservation of soil and moisture.
- ✓ The sites for gully plugs may be chosen whenever there is a local break in a slope to permit accumulation of adequate water behind the bunds.

6. RAINWATER HARVESTING THROUGH CONTOUR BUNDS

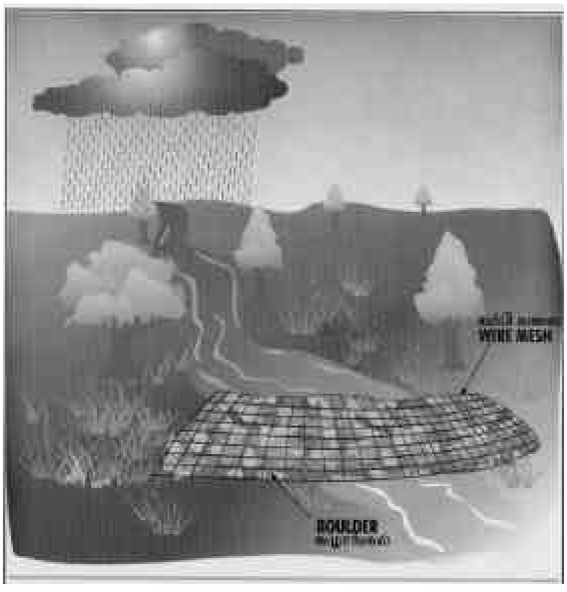
Contour Bunds are an effective method of conserving soil moisture in a watershed for long periods.

- ✓ These are suitable in low rainfall areas where the monsoon run off can be captured by constructing bunds of equal elevation on the sloping ground all along the contour.
- ✓ Flowing water is intercepted before it attains an erosive velocity by keeping a suitable space between bunds.
- ✓ Spacing between two contour bunds depends on the slope of the area as well as the permeability of the soil. The less permeable the soil, the closer the bunds should be spaced.
- ✓ Contour bunding is suitable on land with moderate slopes without terracing.

7. RAINWATER HARVESTING THROUGH A GABION STRUCTURE

This is a kind of check dam commonly constructed across small streams to conserve stream flows with practically no submergence beyond the stream course.

- ✓ A small bund across the stream is made by putting locally available boulders in a mesh of steel wires and anchoring them to the stream bank.
- ✓ The height of such structures is around 0.5 m and is normally used in the streams with widths of less than 10m.

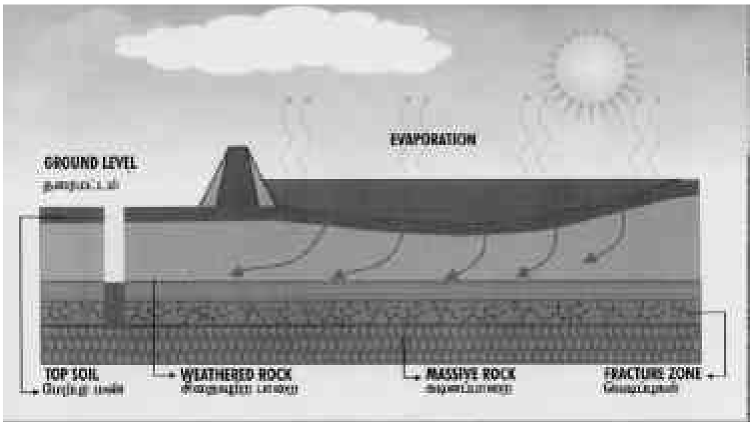


- ✓ The excess water over flows this structure, storing some water to serve as a source of recharge. In time, the silt content of the stream water is deposited in the interstices of the boulders. With the growth of vegetation, the bund becomes quite impermeable and helps in retaining surface water run off for a sufficient time after rainfall to recharge the ground water table.

8. RAINWATER HARVESTINGTHROUGH A PERCOLATION TANK

A percolation tank is an artificially created surface water body, submerging a highly permeable soil in its reservoir, so that surface runoff is made to percolate and recharge ground water storage.

- ✓ A percolation tank should be constructed preferably on second to third order streams, located on highly fractured and weathered rocks which have lateral continuity down stream.
- ✓ The recharged area down stream should have a sufficient number of wells and cultivable land to benefit from the augmented ground water.



RAIN WATER HARVESTING THROUGH PERCULATION TANK

- ✓ The size of the percolation tank should be governed by the percolation capacity of the strata in the tank bed. Normally, percolation tanks are designed for a storage capacity of 0.1-0.5 MCM. It is necessary to design the tank to provide a ponded water column generally between 3-4.5 m.
- ✓ The percolation tanks are mostly earthen dams with masonry structure only for the spillway. The purpose of the percolation tanks is to recharge the ground water in storage and hence seepage below the seat of the bed is permissible. For dams up to 4.5 m height, cut off trenches are not necessary and keying and benching between the dam seat and the natural ground is sufficient.

9. RAINWATER HARVESTING THROUGH CHECK DAMS/ CEMENT PLUGS/ NALA BUNDS

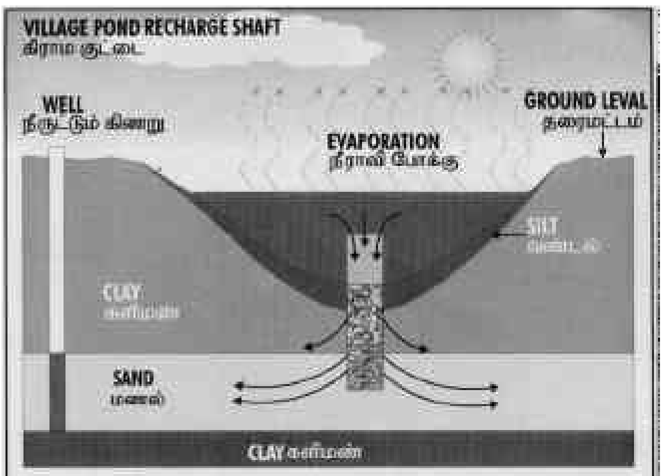
Check dams are constructed across small streams having gentle slopes. The site selected should have a permeable bed of sufficient thickness or weathered formation to facilitate the recharge of stored water within a short span of time.

- ✓ The water stored in these structures is mostly confined to stream course and the height is normally less than 2 m and excess water is allowed to flow over the wall. In order to avoid scouring from excess run off, water cushions are provided at downstream.

- ✓ To harness the maximum run-off in the stream, a series of such check dams can be constructed to have recharge on a regional scale.
- ✓ Clay-filled cement bags arranged as a wall are also being successfully used as a barrier across small nalas. At some places, a shallow trench is excavated across the nala and the space is backfilled with clay. Thus a low cost check dam is created. On the upstream side, clay-filled cement bags can be stacked on a slope to provide stability to the structure.

10. RAINWATER HARVESTINGTHROUGH A RECHARGE SHAFT

This is the most efficient and cost-effective technique to recharge an unconfined aquifer overlain by a poorly permeable strata.



RAIN WATER HARVESTING THROUGH RECHARGE SHAFT

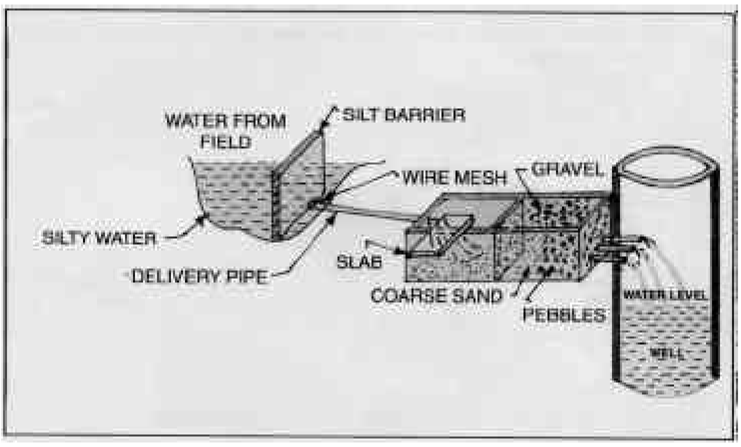
- ✓ A recharge shaft may be dug manually if the stratum is constructed of non-collapsing material. The diameter of the shaft is normally more than 2 m.
- ✓ The shaft should end in a more permeable stratum below the top impermeable strata. It may not touch the water table.

- ✓ The unlined shaft should be backfilled, initially with boulders/cobblestones, followed by gravel and coarse sand.
- ✓ If there is a lined shaft, the recharge water may be fed through a smaller conductor pipe reaching up to the filter pack.
- ✓ These recharge structures are very useful for village ponds where a shallow clay layer impedes the infiltration of water to the aquifer.
- ✓ It is seen that in the rainy season, village tanks are completely filled up, but water from these tanks does not percolate down, due to siltation, and tube wells and dug wells located nearby remain dry. The water from village tanks evaporates and is not beneficial.
- ✓ By constructing recharge shafts in tanks, surplus water can be recharged to ground water. Recharge shafts of 0.5-3 m diameter and 10-15 m deep are constructed, depending upon the availability of water. The top of the shaft is kept above the tank bed level, preferably at half of the full supply level. These are back-filled with boulders, gravel and coarse sand.
- ✓ In the upper portion of 1 or 2 m deep, brick masonry work is installed for the stability of the structure.
- ✓ Through this technique, all the accumulated water in a village tank above 50% capacity would be recharged to groundwater. Sufficient water will continue to remain in the tank for domestic use after recharge.

11. RAINWATER HARVESTINGTHROUGH DUG WELL RECHARGE

Existing and abandoned dug wells may be utilized as recharge structures after cleaning and desilting the same.

- ✓ The recharge water is guided through a pipe from a desilting chamber to the bottom of the well or below the water level to avoid souring the bottom and trapping air bubbles in the aquifer.

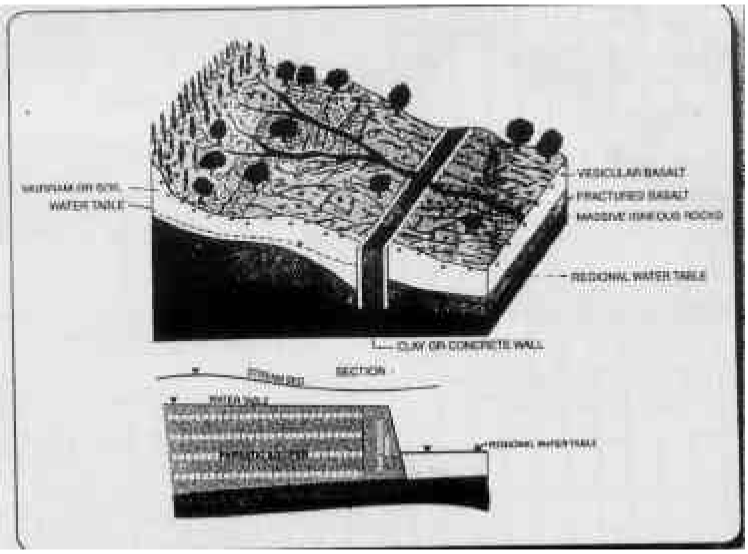


- ✓ Recharge water should be silt-free and for removing the silt contents, the runoff water should pass either through a desilting chamber or filter chamber.
- ✓ Periodic chlorination should be done for controlling bacteriological contamination.

12. GROUNDWATER DAMS OR SUB-SURFACE DYKES

Sub-surface dykes or underground dams are sub-surface barriers across streams which retard the base flow and store water upstream below the surface. By doing so, the water levels upstream of groundwater dams rise, saturating otherwise dry parts of the aquifer.

- ✓ The site where a sub-surface dyke is proposed should have a shallow, impervious layer with a wide entranceway and narrow outlet.
- ✓ After the selection of a suitable site, a trench of 1-2 m wide is dug across the breadth of the stream down to the impermeable bed. The trench may be filled with a clay or brick concrete wall up to 0.5 m below ground level.
- ✓ For ensuring total imperviousness, PVC sheets of 3000 PSI tearing strength at 400 to 600 gauge or low density polythene film of 200 gauge can also be used to cover the cut-out dyke faces.
- ✓ Since the water is stored within the aquifer, flooding of the land can be avoided and the land above the reservoir can be utilized even after the construction of the dam. No evaporation loss from the reservoir and no siltation in the reservoir take place. A potential disaster, like the collapse of the dam, can also be avoided.



5. RECOMMENDATIONS

Following the above descriptions and according to the site conditions and other considerations like ecological impact and sustainability, it appears that several techniques are **not** recommendable for the International Zone.

Accordingly, a classification is proposed on the same:

1. Recharge Pit	**Only in upper area**
2. Recharge Trench	**YES**
3. Tubewell	**Banned**
4. Recharge Well	**Only in the upper area and after careful study**
5. Gully Plug	**YES**
6. Contour Bund	**YES**
7. Gabion Structure	**YES**
8. Percolation tank	**YES**
9. Check Dam / Cement plug / Nala Bund	**YES**
10. Recharge shaft	**Banned**
11. Dugwell Recharge	**Very careful design and maintenance required**
12. Groundwater Dams / Subsurface Dyke	**YES**

E. Rooftop Rainwater Harvesting System

1. What is Rooftop Rainwater Harvesting?

- Collection
- Filtration
- Storage
- Usage
- Recharge

2. Advantages of rainwater usage

There are many aspects to RWH, each of which must be studied and managed correctly, if the overall system is going to run efficiently. They may be classified as follows:

i) Water usage management
ii) Water quality and other health issues
iii) Water collection hardware (storage tanks)
iv) Financial considerations.

Amongst the advantages, we can emphasize:

- Possible reduction of detergent consumption over 50 %
- No calcifying of the washing machine, no additives necessary for lime reduction
- The ion-poor rain water reduces the occurrence of urine stones at the WCs
- The soft rain water offers an optimal irrigation medium for plants
- The saving of expensive water and, eventually, wastewater fees.

3. USE of harvested rainwater

Non-potable	Potable Purpose
Flushing	after ensuring quality (SODIS treatment)
Floor washing	
Washing clothes	
Gardening	

4. Implementation

Rooftop rainwater harvesting should not be considered in isolation, but rather as part of a total system to meet the overall water requirements of a household or community.

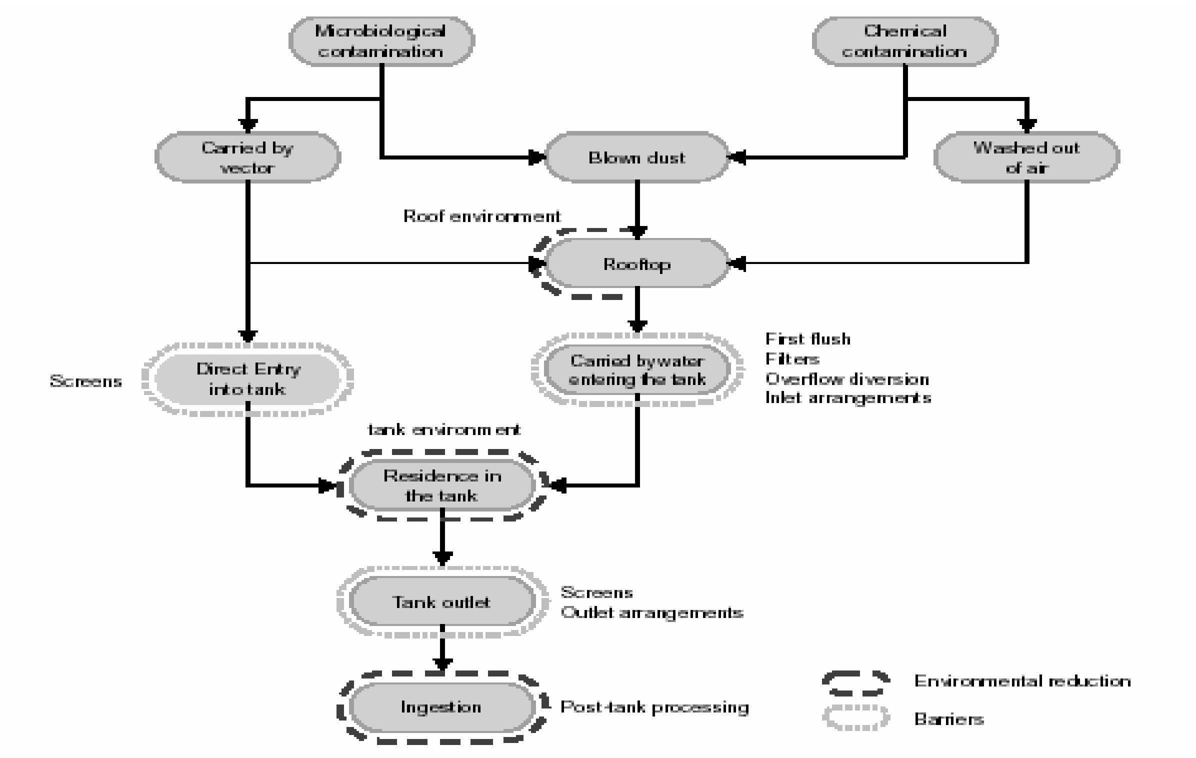
In many cases it may serve as a 'top up' rather than as a main source, and in all cases it should be considered as part of a range of possible supply approaches. Roof water harvesting is fundamentally different from most water supply options. These differences have profound effects on the management and implementation of any project involving roof water harvesting:

• It is based on a finite volume of water that can be depleted if not well managed, making it a poor candidate for community supply unless strong measures are taken to prevent overuse.

• It is highly seasonal in nature, meaning that there must also be another water source available. This source (or sources) must be able to cope with the demands of households using roof water harvesting, especially as the largest demand will be in dry periods. It does not, however, have to be as high in quality.

• *Domestic* roof water harvesting requires a large number of small civil works rather than the large-centralized works of most water projects, requiring different approaches to management.

• The cash flow of roof water harvesting systems is that of a large up-front cost with extremely small maintenance charges. This is in contrast with most water supply systems, where maintenance is a large part of the overall costs. Most water supply projects are cost-based on donor funded initial works with users paying for upkeep – this paradigm is unsuited to DRWH.



Pollution control in RWHS

When installing a rainwater system, please ensure that: NOT SUITABLE FOR DRINKING signage is fixed next to all rainwater system faucets.

5. System Design

The range of opportunities varies from traditional rainwater collecting managed by huge banana leaves up to clever computer management systems used in industrialized nations. Also, there are big differences in the amount and quality of collected water. In some cases, water is caught in small pots to supply the fresh water needed for one day. On the other end of the spectrum, we can see systems which have sufficient collection surface area and storage capacity to provide enough water to meet the full needs of the user (including water for cooking, bathing, washing and irrigation). Between these two extremes exists a wide variety of different user patterns or regimes.

Furthermore, the usage of a Rainwater Harvesting-System (RWHS) is determined by many inter-related circumstances. Some of them are listed below[11]:

- **Rainfall quantity (mm/year)** – This is the total amount of water available to the consumer. It is a product of the total available rainfall and the collection surface area with a loss coefficient included to allow for evaporation and other losses. The mean annual rainfall data will tell how much rain falls in an average year.
- **Rainfall pattern** - Climatic conditions vary widely throughout the world. A climate where rain falls regularly throughout the year will mean that the storage requirement is low and hence the system cost will be low. On the other hand, where rainfall falls in a short time, a big storage capacity is required which.
- **Water quality** – Depending on the quality, collected water is used for different purposes. Water may get polluted due to contact with the environment while falling, from the roof surface and gutter system while harvesting and from the tank material while storing.
- **Collection surface area (m2)** – Logically, where rooftop catchment systems are used, these are restricted by the size of the roof.

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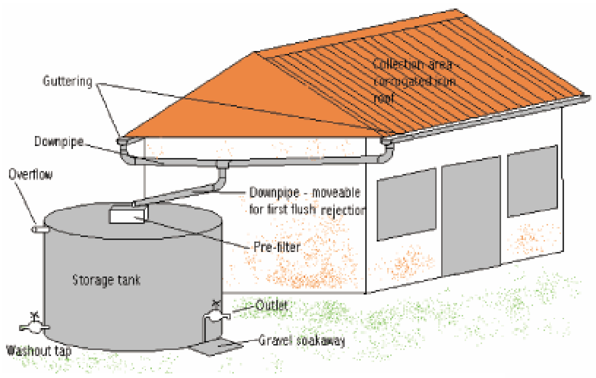
[11] Report A1 - Current Technology for Storing Domestic Rainwater (Part 1)

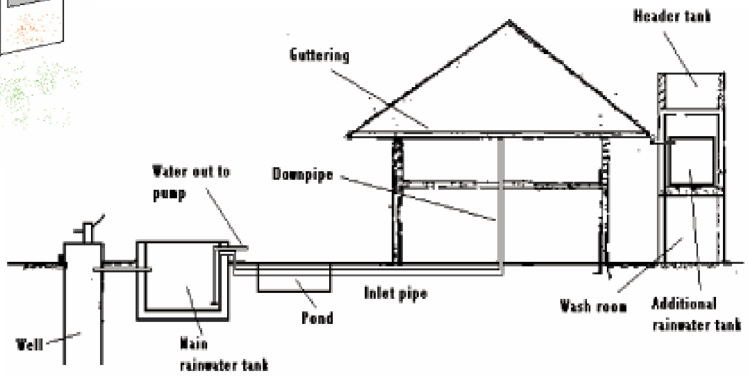
- **Storage capacity (m3)** - The storage tank is usually the most expensive component of the RWHS and so a careful analysis of storage requirement against cost has to be carried out.
- **Daily consumption rate (litres/capita /day or lpcd)** - This varies enormously – from 10 – 15 lpcd a day in some rural parts of India to several hundred lpcd in some westernized parts of India. This will have obvious impacts on system specification.
- **Number of users** - This will greatly influence the requirements.
- **Cost** – A major factor in any scheme.
- **Alternative water sources** – Where these are available, the water supply ideally is a mixture of different supply systems.
- **Water management strategy** – Whatever the conditions, a careful water management strategy is always a prudent measure.

6. Components of a RWHS

Following the way of the water, the main components of a RWHS include: Catchment Surface Area, Guttering, First Flush Systems, Filtration Systems, Storage Facilities and Recharge devices. All individual parts are discussed below.

Roof	-Collector
Gutters & Down pipes	-Transmitters
First-rain separator	-Segregator
Drums	-Filters/Intermediate storage
Silt traps	-Filter chambers
Sumps & OHT	-Storage systems
Bore well, open wells & percolation pits	-Ground water recharge





1. Collection Surfaces

The most common surface for Domestic Rainwater Harvesting (DRWH) is roof area. Nevertheless, it is not the only possibility for collecting water. Likewise, courtyards, paved walking area, plastic sheeting, rocky surfaces etc. can be used. In this document the main emphasis is put on collection from residential roofs.

Typical materials for roofing include iron or steels sheets, ceramic, cementations, a wide range of tiles and slate. Metal roofs are comparatively smooth and are therefore less prone to contamination by dust, leaves, bird-droppings and other debris than rougher tile roofs. Also, they may get hot enough to sterilize themselves. Aluminum is very inert unless it comes in contact with very acidic water[12]. Still the effect on the health of ingesting small amounts of aluminum is unclear and should be investigated before using aluminum. Stainless steel is a very suitable material, but unfortunately very expensive. Steel mildly protected by hot-dip or electrolytic galvanizing is suitable too. Because plastic is neither durable nor cheap, it is not recommended as surface or guttering material.

The efficiency of collection (also called runoff coefficient) depends on the material used: cement tiles reach a year-round efficiency of some 75% while clay tiles range from 25-50% depending on the production method and annual precipitation (Izhu and Liu, 1998). Plastic and metal sheets have an efficiency of 80-90%.

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[12] Report A1

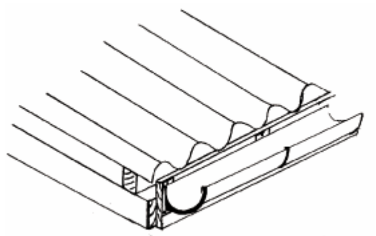
However, this collection efficiency is often greatly reduced because of poor installation and maintenance of gutters and drainpipes.

2. Guttering

Guttering is used for the transport of the water from the roof to the storage facility. Metal is also recommended for guttering. To prevent mixing debris and water, it is recommended to cover the guttering with a sieve.

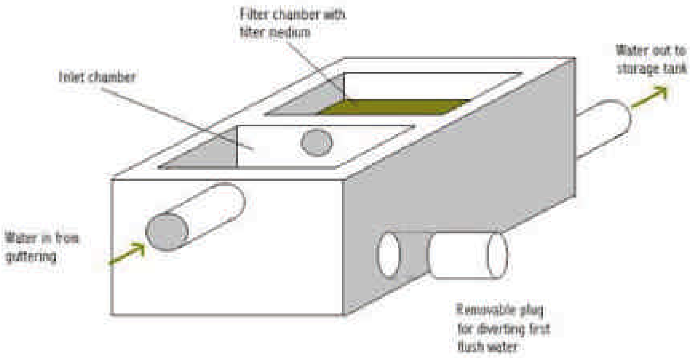
Sizing of Rainwater Pipes for Roof Drainage

Sl.No	Dia of Pipe (mm)	Average Rainfall (mm)	Roof Area Sq.m
I	50	13.4	8.9
II	65	24.1	16
III	75	40.8	27.0
IV	100	85.4	57.0
V	125	---	---
VI	150	---	---



3. First Flush Systems

The first liters of harvested water will contain unwanted matter like debris, dirt and dust. Furthermore, the concentration of fecal coliform and total coliform is considerably higher in the first liter[13].



Without a First Flush System (FFS) these matter will be washed into the tank.

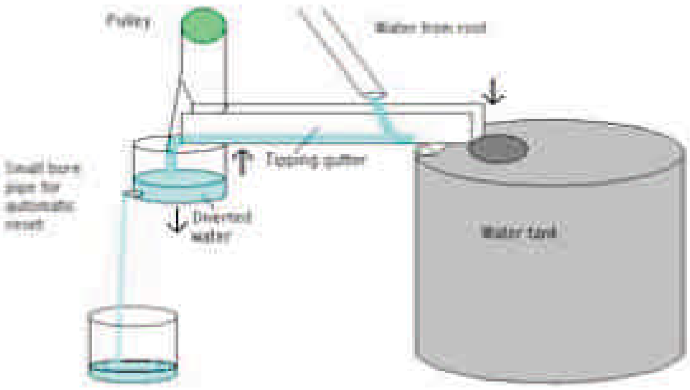
A First Flush System diverts the first liter of the rain and therefore avoids contamination of the water. It is suggested to ensure a minimum of five liters of "foul-flush".

There are a number of simple systems which are commonly used and a number of other, more complex, arrangements.

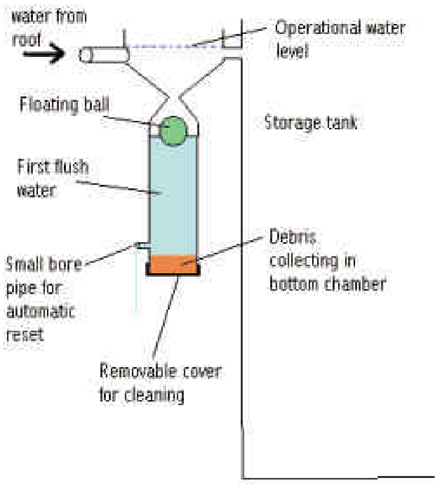
[13] N.,Ghazali, et. Al. June 1989, "Water Research WATRAG Vol. 23, No. 6" Pertanian Malaysia Univ. Serdang, Dept. of Environmental Sciences

The simpler ideas are based on a simple, manually operated arrangement whereby the inlet pipe is moved away from the tank inlet and then replaced again once the initial first flush has been diverted. This method has obvious drawbacks in that there has to be a person present who will remember to move the pipe.

Slightly more sophisticated methods include arrangements such as those shown below, where the stopper in the inlet chamber can be removed to allow the first flush to be diverted.



The most common system uses a bucket which accepts the first flush.



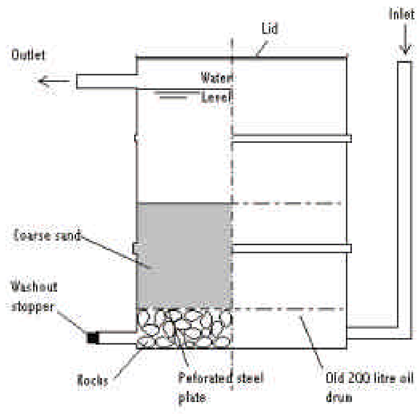
The weight of this water off-balances a tipping gutter which then diverts the water back into the tank. The bucket then empties slowly through a small-bore pipe and automatically resets. The process will repeat itself from time to time if the rain continues to fall, which can be a problem where water is really at a premium. Another system that is used relies on a floating ball that forms a seal once sufficient water has been diverted. The seal is usually made as the balls rises into the apex of an inverted cone.

The ball seals the top of the 'waste' water chamber and the diverted water is slowly released, as with the bucket system above, through a small bore pipe.

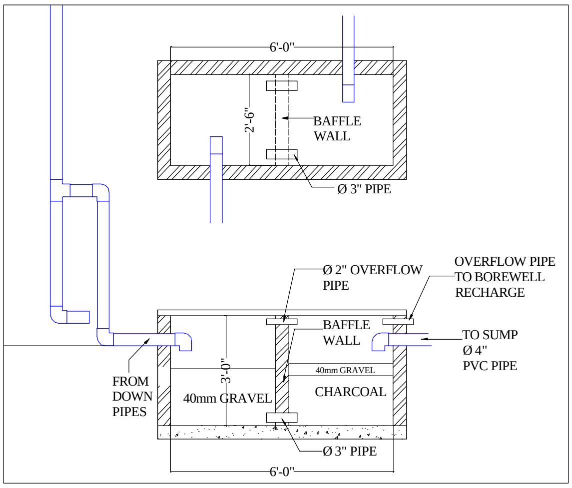
Although the more sophisticated methods provide a much more elegant means of rejecting the first flush water, practitioners often recommend that very simple, easily maintained systems be used, as these are more likely to be repaired if failure occurs.

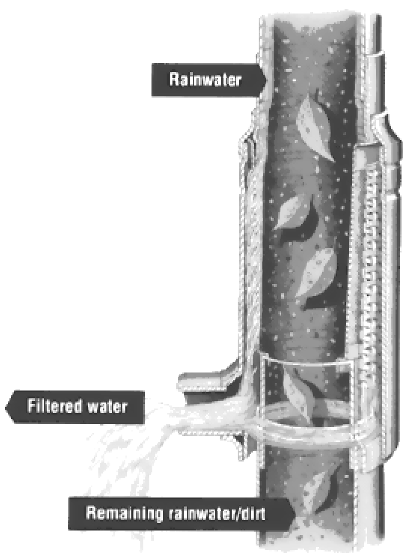
4. Filtration Systems

Again, there is a wide range of possibilities to treat water before it enters the tank. The level of sophistication also varies, from rudimentary to high tech solutions. In general, the technique should be applied depending on the purpose of water usage, the level of pollution and the inflow-speed. To give a basic understanding of filtration, an upflow and filter is shown here.



Silt trap





A German company, WISY, has developed an ingenious filter which fits into a vertical drain pipe and acts as both filter and first-flush system. The filter cleverly takes in water through a very fine (~0.20 mm) mesh while allowing silt and debris to continue down the pipe. Over 90%of the water is collected. Larger models handle run-off from roof areas of up to 500 m2.

The WISY filter (down pipe and high capacity below ground versions) - Source: WISY catalogue Wisyag@t-online.de

5. Storage Facilities

The storage reservoir is usually the most expensive part of the system, so one has to pay close attention to its design and construction. The tank must be constructed so that it is durable and watertight, and so that the collected water does not get contaminated.

There are loads of options for storage facilities. For storing larger quantities of water, usually tanks or cisterns are used. These vary in size, shape, material and price.

There are three categories of storage reservoirs:

1. Surface or above-ground tanks (most common if the collection surface is elevated –a roof);
2. Sub-surface or underground tanks (common for ground catchment systems);
3. Dammed reservoirs for larger catchment systems.

Materials for surface tanks include metal, wood, plastic, fiberglass, brick, inter-locking blocks, compressed soil or rubble-stone blocks, ferrocement and concrete.

The material and design of sub-surface tank walls must be able to resist the soil and soil water pressures from outside when the tank is empty. An empty tank can float like a boat when the groundwater table rises! Careful location of the tank, and keeping it partly above ground level (and way above the groundwater table) will help to solve this problem; heavier materials are another option, but may have a serious cost implication.

A common technology successfully used in Auroville is based on ferrocement, but others like stone masonry seem to be competitive.

Tank size varies depending on the rainfall pattern and the user group: households may need a tank of from 1m3 to more than 40m3, while schools and hospitals may need tanks up to 100m3. When there are long dry seasons, roof collection area and tank size will be large, but rationing (good management) and the use of alternative sources significantly reduces the surface area and tank volume. In general, required roof area and tank volume increase as total rainfall decreases, or where rainfall patterns become erratic.

From the point of view of cost-effectiveness, in arid areas or areas with poorly distributed rainfall, where very large and expensive surface areas and tank volumes are needed, rainwater is best seen as a supplementary water source. However, in semi-arid areas with well-distributed rainfall, roof catchment supplies are much cheaper than water trucked or piped over long distances (Gould and Nissen-Petersen, 1999).

6. Needs and specification

Tanks need to be watertight. They also need to hold the required volume and to be durable (say 25 years before they become unserviceable). Beyond these basic requirements, we can list many further specific requirements. Tanks should:

- ✓ have a way of being charged with water without unduly disturbing tank-bottom sediments and if possible maintaining stratified flow (the bacterial quality of outlet water is maximized if the flow through the tank resembles 'pipe flow', namely 'last in is last out'
- ✓ be able to handle excess input by overflowing in a convenient and safe manner – preferably without losing water unnecessarily via the tank (such water may drop unwanted sediment in the tank)
- ✓ have a means by which the water can be extracted which is convenient for the user and which does not pollute the water left behind (as dipped buckets may)
- ✓ exclude vermin and, as far as possible, mosquitoes
- ✓ exclude light (so that algae do not grow and larval growth is inhibited)
- ✓ have some form of ventilation, especially if there is not an efficient filter to prevent organic material from entering the tank and decaying there
- ✓ be easy to access for cleaning (where cleaning is needed) and not likely to be damaged during cleaning
- ✓ have a sufficient structural safety factor to withstand wear and tear, some impacts and occasional large natural forces like winds and (in places) earthquakes
- ✓ not present hazards to passers-by or small children
- ✓ not give the water a bad taste

7. Overview of various tank designs.

1. External Reinforced Brick Tanks

Brick material is widely used in India and thus it is readily available. It is ideally suited for wall construction. Due to the poor strength in tension, the poor adhesion of one brick to another, and the relatively large quantity of cement needed, it is not suited very well for larger volume tanks. Nevertheless, there are some options like using external steel reinforcements, to improve the quality.

PROS	CONS
⇨ low material cost ⇨ material locally accessible ⇨ well known and widely used technology	⇨ not ideal for round tanks ⇨ poor in tension - needs reinforcement

2. Rammed Earth Tanks

As the name suggests the technique involves earth rammed between two shutters, using a rammer or a tamp. The shuttering is removed to reveal the wall. Walls are usually constructed in sections of a few feet long by a foot or two deep with shuttering moved along to form a continuous wall. The shuttering is then raised and placed on top of the first 'lift' to construct the subsequent 'lifts'.

This "green" architecture is appreciated because it has a low energy input and excellent thermal properties.

Its longevity and stability is attested to by the weather resistance of houses which were built hundreds of years ago. Still there are some particular problems.

PROS	CONS
⇨very low material cost ⇨ material locally accessible ⇨simple technology that easily taught to semi-skilled worker	⇨not suitable for below-ground tanks/cisterns ⇨in cases of leaks serious problems can develop ⇨high labour input

3. Stabilized-Soil Tanks

Stabilized, compacted, soil block technology involves compacting suitable soil, which is often mixed with a small percentage (typically 5 – 10%) of cement, using a manual or hydraulically assisted ram or press. This compaction reduces the gaps in the material and hence its susceptibility to attack from water. Special molds can be manufactured to produce blocks of different shapes for special purposes.

PROS	CONS
⮡ Reduced cement content resulting in inexpencive blocks	⮡ Low wet strength ⮡ Reduced cement content must be balanced against lower strength requiring thicker walls ⮡ Needs specialized tools for compacted blocks ⮡ Low tensile strength or block

4. Lining Tanks with Plastic Bags

Plastic linings can considerably reduce the cost of the tank by removing the need for

any construction work to make it watertight. Indeed they can be simply placed in a hole to form a very cheap and portable tank (although a cover should be constructed). Plastic liners also allow removal for inspection, cleaning, maintenance and occasional repair.

The technique uses simple tools and can be taught in a couple of hours to a reasonably skilled craftsperson. It is suggested to use plastics with a woven structure, because they seem to be more resistant.

PROS	CONS
⮡ Greatly reduced cost ⮡ Portable ⮡ No clambering is required during construction ⮡ Can be removed for cleaning/inspection ⮡ Can be batched produced	⮡ Fragile - likely to tear, subjects to pin holes ⮡ UV degradation ⮡ Joining requires specialized technique

5. Simple Underground Tanks in Stable Ground

The Open University in Sri Lanka experimented with creating underground tanks using stabilized soil with bamboo, reinforcing and a plastic liner for waterproofing. Two-third of the cost of these tanks are absorbed for the cover. One problem discovered in the study is that tanks have been broken due to rising water tables and puncturing by tree roots. The pros and cons are listed down below.

PROS	CONS
➪Greatly reduced cost sue to lower wall thickness ➪More difficult to empty by leaving tap on ➪Can be made unobstrusive	➪Water extraction is more difficult ➪Leaks or failures are more difficult to detect ➪Contamination of the tank from surface runoff ➪Tree roots can demage the structure ➪Sensetive to groundwater level rising

6. Partly Below Tanks

Several problems can be overcome by placing the tank partly above and partly below the ground. These kinds of tanks are already successfully used in Auroville. Manfred is using a 100 m^3 tank at Auromodele. They are combining the advantages of above ground and below ground tanks.

PROS	CONS
➪Lower material requirement ➪Reasonable unobstusive ➪Lower cost due to thinner walls ➪Available locally at CSR	➪Requires a pump ➪Leaks or failures are difficult to detect ➪Tree roots can damage the structure

7. Waterproof coatings

Waterproof paints are quite common in the developed world where they are used to seal ponds, swimming pools, etc. These paints are available and local variants may be developed. Quality control may become a major issue, as any uncoated sections could result in a dangerous, catastrophic failure of the tank.

8. Sizing the system

Usually, the main calculation carried out by the designer when planning a domestic RWH system will be to size the water tank correctly to give adequate storage capacity. The storage requirement will be determined by a number of inter-related factors. They include:

- ✓ local rainfall data and weather patterns
- ✓ size of roof (or other) collection area
- ✓ runoff coefficient (this varies between 0.5 and 0.9 depending on roof material and slope)
- ✓ user numbers and consumption rates

The style of rainwater harvesting i.e., whether the system will provide a total or partial supply, will also play a part in determining the system's components and their size.

There are a number of different methods used for sizing the tank. These methods vary in complexity and sophistication. Some are readily carried out by relatively inexperienced, first time practitioners while others require computer software and trained engineers who understand how to use this software. The choice of method used to design system components will depend largely on the following factors:

- ✓ the size and sophistication of the system and its components
- ✓ the availability of the tools required for using a particular method (e.g. computers)
- ✓ the skill and education levels of the practitioner / designer

Below we will outline 3 different methods for sizing RWH system components.

1. Method 1 – demand side approach

A very simple method is to calculate the largest storage requirement based on the consumption rates and occupancy of the building. As a simple example, we can use the following typical data:

Consumption per capita per day, C = 50 liters

Number of people per household, n = 6

Longest average dry period = 200 days

Annual consumption = C x n = 300 liters

Storage requirement, T = 300 x 200 = 60,000 liters

This simple method assumes sufficient rainfall and catchment area, and is therefore only applicable in areas where this is the situation. It is a method for acquiring rough estimates of tank size.

2. Method 2 – supply side approach

In low rainfall areas or areas where the rainfall is not evenly distributed, more care has to be taken to size the storage properly. During some months of the year, there may be an excess of water, while at other times there will be a deficit. If there is enough water throughout the year to meet the demand, then sufficient storage will be required to bridge the periods of scarcity. As storage is expensive, this should be done carefully to avoid unnecessary expense. This is a common scenario in many developing countries where monsoon or single wet season climates prevail.

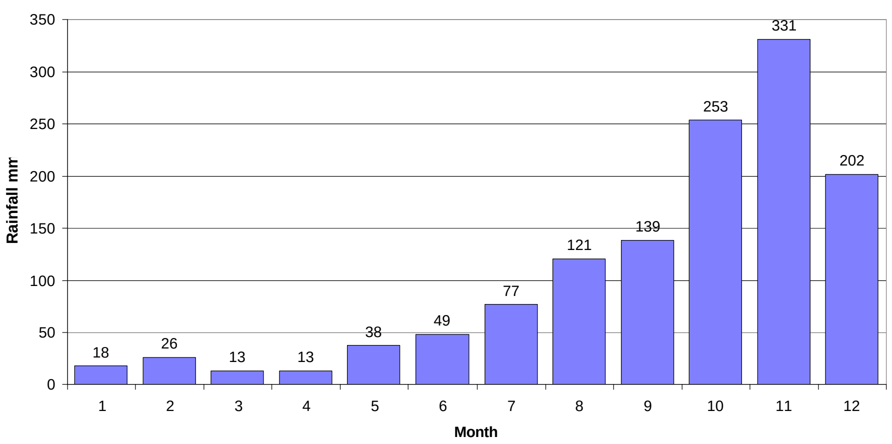
The example is designed for a system at a medical dispensary in a village around Auroville.

Demand	**Supply**
Number of staff: 6 Staff consumption: 25 l/c/d* Patients: 30 Patient consumption : 10 l/c/d Total daily demand: 450 litres	Roof area: 190m2 Runoff coefficient** (for new corrugated GI roof): 0.9 Average annual rainfall: 1280mm per year Daily available water (assuming all is collected) = 190 x 1280 x 0.9)/ 365 = 599 litres

*l/c/d – litres per capita per day

** Run-off coefficient values vary between 0.3 and 0.9 depending on the material of the catchment area. It takes into consideration losses due to percolation, evaporation, etc.

Monthly Average Rainfall on a 35 years (1968 - 2003) in Auroville area



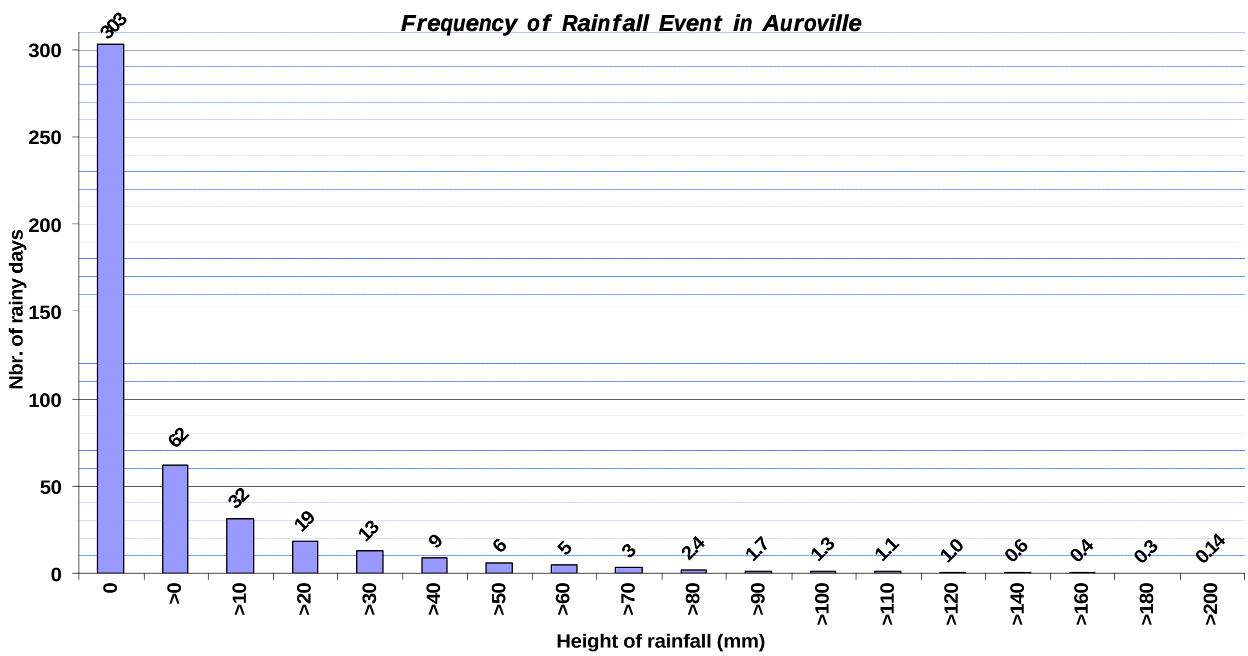
F. Some understanding

While promoting Rainwater Harvesting and Water Saving techniques, it is important to understand their feasibility and practicality.

It seems relatively obvious that an area with a well sprayed rainfall pattern may develop rainwater harvesting structures at a much more affordable price than let's say Rajasthan. However, Rajasthan and other very dry areas are well equipped with such structures, which demonstrates that the problem must be seen in its own context. In the end, if there is no other source of fresh and clean water available, the cost is not anymore the only relevant criteria. But let's see further what it means in the Auroville context.

Period : June 1968, December 2003 Sources: Auroville Certitude, Pondicherry , Auroville Harvest	
Average rainy days per year : 62	Maximum rainfall on 1day : 362 mm
Average rainfall per year : 1280 mm	Maximum rainfall in 2 days : 416 mm
Maximum rainfall per year : 1910 mm	Maximum rainfall in 3 days : 478 mm
Minimum rainfall per year : 731 mm	Maximum Rainfall in a month : 700mm

From the Indian Meteorological Department, the heaviest rainfall in 2 days is suppose to be around 600mm and 700 for 3 days, about 50% above the recorded values.



Now, while going through the number of rainy days versus height of rainfall, we can realize that in fact rainfalls of significant value are few and heavy downpours are not ,on the average, frequent. Practically, a first sizing of rainwater harvesting structures as defined earlier may as well follow the same ratio. For example, if one believes that a recharge structure should be able to absorb nearly every rainfall, one can consider it achieved with a system sized for 120mm of rain per day.

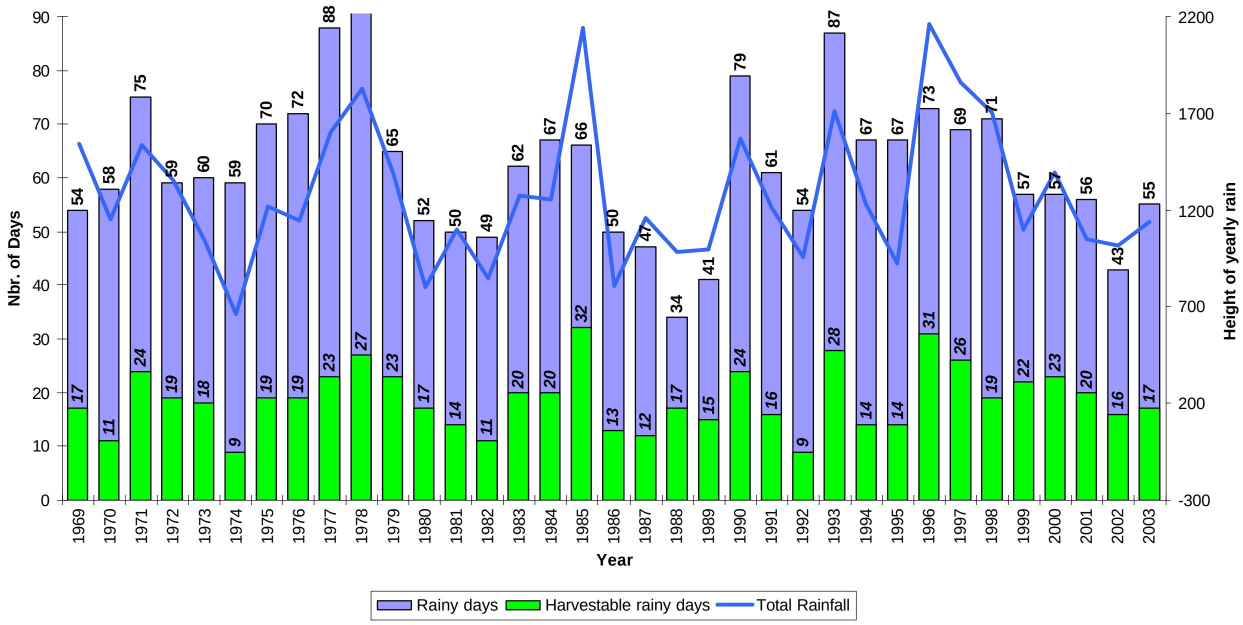
Of course, a storm water control structure should be defined accordingly, starting from evaluated runoff from non-built areas, and then adding extra capacity for times of exceptional rainfall.

When analyzing the requirements for a roof rainwater structure, it is also important to define first how much rainfall it is possible to harvest. While, generally speaking, the method is simply following runoff coefficient values, a careful look at rainfall data may lead to a serious rethinking.

First, it is clear that not all of the rain can be collected: below a certain intensity, the water gets evaporated before it reaches the drain. Then, for the rainfall above this limit, still an important part gets lost through the splash effect, and more through the first flush system (0.90), filtration system and others. Practically, it means that the number of rainfalls creating storable or infiltrable water is even less than what is stated above. Even when there is sufficient rainfall, there is still some water lost before reaching the storage or infiltration devices.

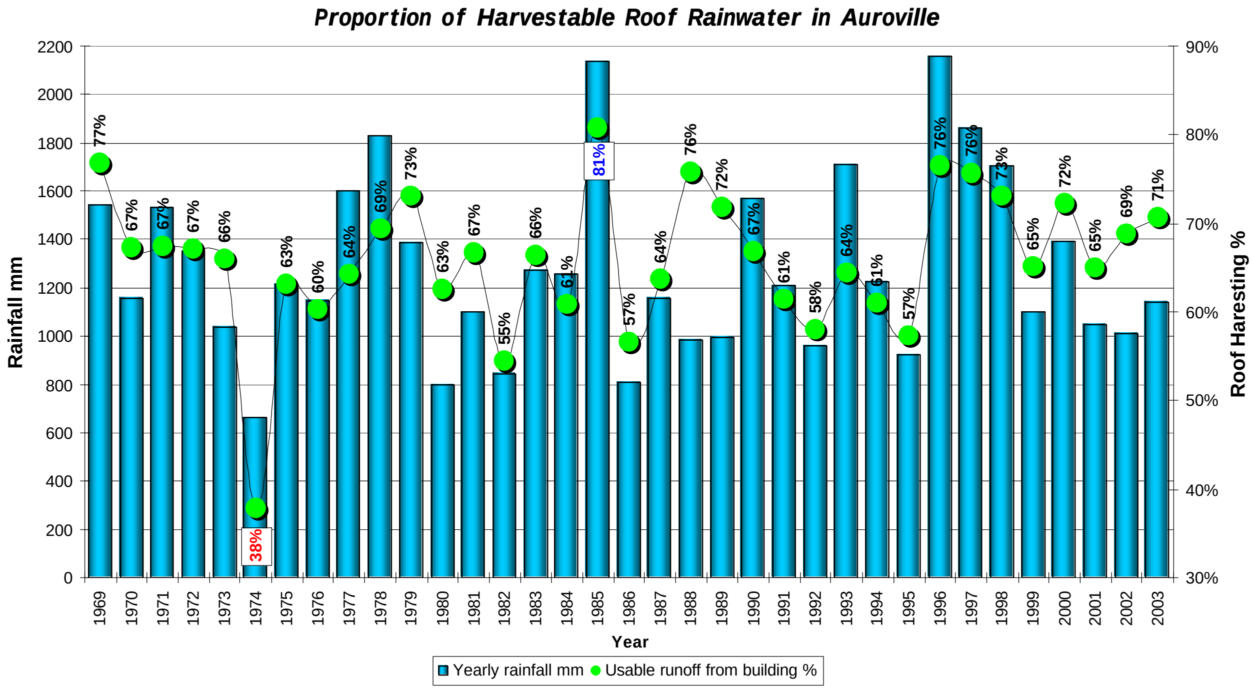
After various simulations, we came to the conclusion that no rainwater is collected below 20 mm of rain per day. Of course, this may fluctuate a bit due to the intensity of the rainfall and roof materials. Moreover, about 5 mm is lost through the components of the system itself.

Number of days Generating Runoff from a Roof in Auroville



The following table synthesizes this analysis with average values, while Sim Tanka values (from a well known software program for the sizing of a roof rainwater system), are somewhat confirming these results.

Harvest evaluation				**Sim Tanka`**		
Average Yearly Rainfall	1281			Drought year	534	42%
Rainy days	62			Below average rain	676	53%
Harvestable rainy days	19	*30%*		Average rain	819	64%
Harvestable rain	864	*67%*		Above average rain	1077	84%



It is then clear that the recharge of the system is happening sporadically, which means that the storage facility, if any, must have a large capacity if to be useful at all.

We come to the conclusion that it is possible to harvest about 86,000 liters of rain for 100 sqm of drained roof area on the average. This does not mean that the storage system must be that large. The volume of the tank must be evaluated as per rainfall data and water demand.

For example, using daily rainfall data form January 1969 to December 2003, in a building of 100 sqm using 200 liters of rainwater per day, a tank of 65 m3 will cover all the needs, with a shortage of water once every 4 years, and this for a few weeks maximum.

G. Conclusions

In the planning process of the IZ, many varieties of rainwater harvesting should be integrated, taking into account storm water management and landscaping. The design should be guided by Auroville's rich experience,

The main aim of a RWHS is to reduce dependency on groundwater. Under local conditions, it is not recommended to use RW for every purpose in order to meet the full water need. On the other hand, it is recommended to use RW for gardening, toilet flushing, washing utensils and recharging the ground water table. The design of the collection area and the storage volume should be done carefully. Parameters mentioned in the beginning of this chapter should be considered. In Auroville, the actual cost for one stored liter, using a variety of techniques, is between 1.5- 2.5 Rupees. By improving storage technology and increasing the volume, we may expect the price to drop down to 0.5 Rupees/l[14].

Partly underground tanks combine the economic affordability of underground tanks with the safety and desirability of an above-ground tank. These tanks are already successfully used in Auroville and experiences have been satisfying. The water level fluctuation in the IZ is great, therefore the placing and choice of tanks has to be carefully considered.

Covering tanks will provide several advantages. First, it avoids people falling accidentally into tanks. Second, darkness will stop photo-synthesis and therefore stop the growth of algae inside the tank. Third, the quality of the water can be maintained.

To protect the water quality it is strongly recommended to control the inflow quality (effective pre-filtration) and protect the tanks against run-off. Also, the regular cleaning of the collecting surface, roof, gutters and the tank will help maintain water quality. All inflow and outflow pipelines should be protected against mosquitoes.

The choice of an appropriate first flush and filtration system has to be made carefully. As mentioned above, there is a wide range of choices. Basically, the more sophisticated techniques do not need that much maintenance and are therefore recommended. Besides technical factors, good management is also required to guarantee well-working RWHS.

The necessity of integrating the design of rainwater water harvesting with conventional building practice, i.e. to interfere minimally in the latter, is of great importance in reducing cost. This also includes incorporating aesthetics.

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[14] Indian government

Plants for The IZ

India is a land of contrasts. It has a great variety of climatic zones, and a diversity of physical features. After Brazil, it has the most variety of plant species in the world.

A. The Natural Vegetation Composition

The vegetation of a region is influenced by the climate and also by the topography. The natural vegetation composition of Auroville and the surrounding areas is the Tropical Dry Evergreen Forest [TDEF].[15] "Physiognomically it occurs in the shape of scrub-woodland or thicket; the latter may be dense or discontinuous." [16] The term TDEF is misleading because the climatic regime is not typically tropical due to varying rainfall patterns. "The region is not particularly dry, nor is the formation entirely evergreen as almost 50 per cent of the species are deciduous [deciduous means the leaves fall off the tree seasonally, creating a different appearance of the tree throughout the year]." [2] The climatic classification of the area is anyhow semi-arid.

Dypetes sepiaria

[15] Kehimkar, I. (2000): Common Indian Wild Flowers, Bombay Natural History Society, Mumbai, s. 2

[16] Puri, G.S. et al., 1989, Forest Ecology, Second Edition, Volume 2 Plant Form, Diversity, Communities and Succession, Oxford & IBH Publishing Co. PVT. LtD., s. 267, 297, 298

Typical for the TDEF in this sub-humid climate are evergreen [evergreen means an overall green character and a similar appearance throughout the year, and the leaves remain] or semi-evergreen species with a mixture of deciduous species. "One school considers the effects on Tropical Dry Evergreen Forest by anthropogenic activities. The main argument of this school is that the dry evergreen forests are always in a degraded form … and never in the shape of a true forest." [2]

B. Indigenous Plants for the International Zone

Manilkara hexandra, Memecylon umbellatum, Drypetes sepiaria, Pterospermum suberifolium, Garcinia spicata and *Syzygium cumini* are the most typical species for this forest type in this region. [2] "The ground here is hard and sometime clayey, permitting a rapid flow of water and little percolation. Monsoon provides the rainfall so that a long dry period and a short wet period mark out the yearly cycle of seasons." [17] The species that grow are marked by low bushy growth, a deep root system, small and dark green foliage, shining body surfaces and a spinescence mark. The trees have an overall green character. A special feature common to all plants is the possession of peculiar devices for withstanding periods of drought. [18]

Syzygium cumini

[17] Narayanaswami, R.V., et al., 1971, Outlines of Botany, S. Viswanathan, s. 899

[18] Cramer, L.H. (1993): A Forest Arboretum in The Dry Zone, Institute of Fundamental Studies, Kandy, Sri Lanka, s. 36

Drought-resistant plants in the tropics

- ✓ Small or waxy leaves, which reduce evaporation.
- ✓ Hairy leaves that retain moist air, keeping them cool.
- ✓ Hollow stems, used for storing water.
- ✓ Ability to survive in shallow grassland or on rocky slopes
- ✓ Deep roots, which extract water from the subsoil [19]

Manilkara hexandra

A few of the trees, the leguminous members, bear dissected leaves, either in pinnate or foliolate form. The leaf modification serves as a protection against excessive transpiration during the season of drought. [4] Shrubs have often armed stems with prickles or spines or leaves of reduced dimensions. [4] The indigenous [indigenous means plants which are not introduced, they occur naturally in this area] trees vary in height, with mostly the large deciduous trees demanding light. The evergreens are smaller and can grow in a semi-shaded environment and sometimes completely in the shade of the deciduous trees. Especially in their first years, evergreen and semi-evergreen trees often need shade for growing because the summer sun is too strong and the leaves can get burned.

Indigenous plants are fitted to the climate in the sense that they do not need much care, except in the first years, when minimal care may be necessary.

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[19] Hart, R. (1996): Forest Gardening, Cultivating an Edible Landscape, Chelsea Green Publishing Company, Vermont, USA, s. 14

C. The International Zone: A Park?

The International Zone should be designed to resemble a big natural park. It should be planted in a manner similar to that of the TDEF, only not quite as dense as it would be in nature, which will leave a lot of open spaces for recreational uses, but also good ventilation and a breeze effect. What results is the idea of a big natural park with pavilions inside.

It is important when planting an area to maintain a mix of evergreens, deciduous, semi-evergreen and similarly to take into account the variance in height of the trees, shrubs and groundcover-plants. In the summertime there are hot winds in this area while the climate throughout the year is generally wet.

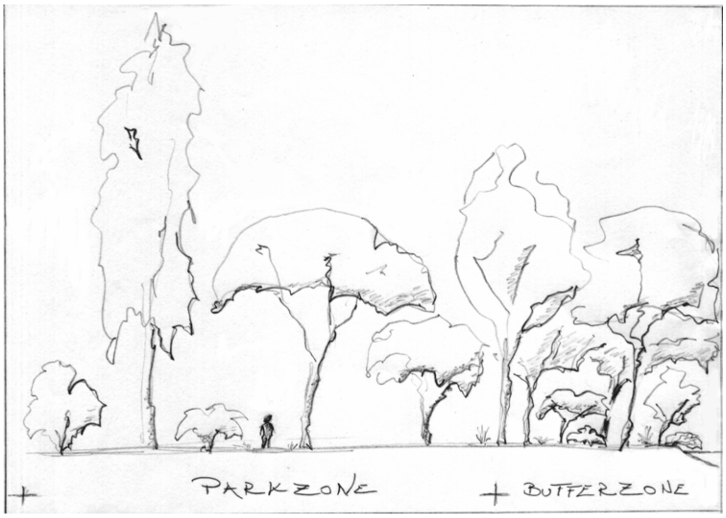
Height differences are necessary to create a rough structure to break the wind in certain area. The wind blows softer through the trees and shrubs and becomes cooler in temperature. To keep an elevated canopy with light and aerated vegetation in a recreational area will create a pleasant, cooling effect, reduce the humidity and allow for open and nice view. Trees are planted for shade and wind control. For example *Tamarindus indicus* is known for its resistance to hurricanes. The shade is important to minimize the temperature on the ground, decreasing evaporation. The different shapes of leaves that exist produce different types of shade, some providing more than others.

Polyalthia longifolia var. pendula

In the landscape of the park, it is important to have a natural diversity of plants species with various styles of arrangement. This way the plants are stronger against sickness, the diversity of animals will increase and the balance of the soil will be provided.

The indigenous species are most adapted to the environmental conditions and so they support the balance of the substance cycle, which is necessary for sustainable development. Deciduous plants lose their leaves in different times of the year, often between January and March or during the hot season in summer.

Evergreens do not lose as many leaves as deciduous species, so they produce less biomass and compost, which is important for the soil and the substance cycle. The leaves of evergreens are thicker and they need more time to become compost.



The plants closest to the water should be denser and consist of indigenous species to create a buffer zone for the water bodies. On the other hand, the spaces closest to the pavilions should be more open with of an emphasis on ornamental plants and gardens.

D. List of Plants Recommended for the IZ

The following lists comprise proposals of plants which can be used in the Park.

Botanical Name	Common Name	Height up to		Notes	Leaf-fall
Large Semi-Deciduous Trees					
Stereospermum personatum		15m			
Medium-Sized Evergreen Trees					
Alangium salvifolium		10m		Canyons	
Barringtonia acutangula		8m		Canyons	
Calophyllum inophyllum	Borneo Mahagony	10m	indigenous		
Cassine glauca		10m			
Diospyros affinis		10m			
Drypetes sepiaria	Veerai	10m	indigenous	typical for TDEF	
Ficus tsjakela		10m			
Garcinia spicata		15m	indigenous	typical for TDEF	
Lepisanthes tetraphylla		8m			
Manilkara hexandra	Wild Chico	8-10m	indigenous	typical for TDEF	
Mesua nagassarium		9m			
Pterospermum suberifolium		12m	indigenous	typical for TDEF	April-May
Pterospermum xylocarpum		12m			
Tricalysia dalzelli	Wellai Marem	10m			
Walsura trifoliolata		8m			
Medium-Sized Deciduous Trees					
Aegle marmelos	Bael fruit	8m		armed	
Albizia amara		8m			
Albizia lebbeck	Mother-In-Law	8m			January-March
Albizia odoratissima		8m			
Albizia procera		8m			
Berrya cordifolia	Halmilla	10m			
Carreya arborea	Kasattai	8m	indigenous		
Crateva magna		12m			
Dalbergia lanceolata		8m			
Dalbergia paniculata		8m			

Delonix regia	Flamboyant	12m			
Erythrina suberosa		8m			
Ficus religiosa		10m		sacred	
Givotia rottleriformis		10m			
Grewia damine		8m			
Gyrocarpus americanus		8m			
Lagerstroemia speciosa	Pride Of India	15m			
Limonia acidissima	Wood Apple	10m		armed	
Phyllanthus emblica	Amula	10m	indigenous		
Pterocarpus marsupium	Vengai	12m			
Sterculia urens	Indian Almond Tree	8m			May-October

Medium-Sized Semi-Evergreen Trees

Azadirachta indica	Neem	10m		sacred	
Ehretia laevis		10m			
Ficus amplissima		8m			
Ficus tinctoria		7m			
Mitragyna parviflora		7m		Canyons	January-March
Polyalthia cerasoides		12m			
Pongamia pinnata	Indian Beech	10m	indigenous	Canyons	January-March
Sapindus emarginata	Soapnut	7m			May-October
Semecarpus anarcardium	Marking Nut	12m			
Strychnos potatorum		10m			
Thespesia populnea	Tulip Tree	8m	indigenous		

Medium-Sized Semi-Deciduous Trees

Cordia monoica		8m			

Small Evergreen Trees

Aglaia elaeagnoida		5m			
Aglaia roxburghiana	Chokkala	6m			
Atalantia monophylla	Wild Lemon	5m		armed	
Atalantia racemosa	Wild Hill Lemon	6m		armed	
Bauhinia monandra		6m			
Bauhinia racemosa	Aaththi	8m	indigenous		
Buchanania axillaris		6m			
Caesalpinia coriaria	American Sumach	3-5m			
Chionanthus zeylanica		7m	indigenous		
Diospyros chloroxylon		4m			
Diospyros ebenum	Ebony	6m	indigenous		

Ficus microcarpa		4m			
Filicium decipiens	Fern-leaf Tree	4m	indigenous		
Ixora arborea		3m			
Pamburus missionis	Wild Orange	6m		armed	
Pleuroustylia opposita		5m			
Polyalthia korinthi	Ulkenda	3m			
Thevetia variegata	Ponnaleri	4m			
Vitex altissima	Kaaddamanakku	7m	indigenous		April-May

Small Deciduous Trees

Acacia chundra		5m		amed	
Acacia leucophloea		6m		armed	
Bridelia retusa		6m			April-May
Butea monosperma	Flame Of The Forest	5-8m	indigenous		
Carissa spinarum					
Cassia fistula	Indian Laburnum	6m	indigenous		April-May
Chloroxylon swietenia	Satinwood	7m	indigenous		April-May
Cochlospermum religiosum	Yellow Silk-Cotton	8m			
Commiphora berryi		5m		Fence	
Commiphora caudata		6m		Canyons	
Dolichandrone falcata		6m			
Firmiana colorata		5m			May-October
Hymenodictyon oxiense		5m			
Lagerstroemia indica	Crape Myrtle	4-5m	deciduous		
Tabebuia argentea	Golden Bell	8m			
Wrightia tinctoria		6m			

Small Semi-Evergreen Trees

Cleistanthus collinus		5m			
Diospyros melanoxylon	Beedi-Leaf Tree	6m			
Diospyros montana		8m			
Ehretia pubescens		7m			
Ficus hispida		5m			
Gardenia gummifera	Gum Gardenia	5m	indigenous		
Gardenia resinifera		4m			
Hibiscus tiliaceus	Hibiscus	8m			
Morinda coreia	Neikottan	2m	indigenous		
Salvadora persica		7m			
Santalum album	Sandalwood	8m			
Streblus asper		**5m**			
Ziziphus mauritiana	Ilenthai	5m	indigenous		
Ziziphus xylopyra		6m		armed	

Cacti, Cactus Type Trees, Succulents and Palms

Adenium obesum	Desert Rose	1,5m	deciduous	
Borassus flabellifer	Toddy Palm, Plamyra Palm		indigenous	Pioneer
Euphorbia nivulia		5m		
Caryota urens	Fishtailpalm	20m	indigenous	
Cereus peruvianus	Column Cactus			
Euphorbia antiquorum	Suthurakkulli	6m	indigenous	armed shrub
Maba buxifolia				
Opuntia spec.				
Phoenix humilis	Wild Date			
Phoenix pusilla			indigenous	armed
Phoenix sylvestris		15-20m		

Big Shrubs

Bambusa ventricosa	Buddhas belly bamboo	4m	evergreen	
Bougainvillea varities	Bougainville	4-5m		armed
Brunfelsia pauciflora		3m	evergreen	
Calotropis gigantea	Crown plant	2m	indigenous, evergreen	
Capparis brevispina		4m	evergreen	
Capparis zeylanica	Ceylon Caper	4m	evergreen	armed
Carissa spinarum		3m	evergreen	
Dichrostachys cinerea	Vidaththul	4m	indigenous, deciduous	armed
Diospyros ferrea		5m	semi-evergreen	
Dimorphocalyx glabellus		5m	evergreen	
Dodonea viscosa	Hopseed Bush	2-3m	indigenous, evergreen	
Flacourtia indica		3m	semi-evergreen	armed
Gmelina asiatica		3m	semi-evergreen	armed
Helicteres isora	Valempuri	2m	indigenous, deciduous	
Hibiscus rosa-sinensis		3m		
Jarenna asiatica		shade	evergreen	
Jasminum varities				
Lantana camara	Shrub verbena	3m		
Maytenus emarginata		3m	semi-evergreen	
Memecylon umbellatum	Ironwood	3m	indigenous, semi-evergreen	
Murraya paniculata		shade	evergreen	
Ochna obtusata	Bird's Eyes Bush	4m	indigenous, deciduous	
Ormocarpum sennoides		3m	deciduous	
Polyalthia korinthi	Ulkenda	3m	evergreen	
Premna alstoni		4m	semi-evergreen	
Psilanthus wightiana	Antenna straggly	2,5m	indigenous, deciduous	
Raufolfia tetraphylla	Pampukaalaachchedi	2m	evergreen	
Salacia chinensis		3m	semi-evergreen	
Securinega leucopyrus		2,5m	deciduous	

Tarenna asiatica		3m	evergreen		
Tecoma stans		5m	deciduous		
Thevetia variegata	Ponnaleri	4m	evergreen		
Vitex negundo	Wellainochichi	2m	indigenous, semi-evergreen		

Small Shrubs

Anisomeles indica	Paeimiratti	1,5m	evergreen
Barleria grandiflora		1m	indigenous
Bauhinia wallichii		1,5m	evergreen
Cassia auriculata		1m	indigenous
Catharanthus roseus	Old Maid	1m	
Eugenia bracteata	Kayaa	1,5m	indigenous, evergreen
Glycosmis pentaphylla	Jamaica Mandarin Orange	1m	indigenous, evergreen
Jatropha podagrica	Guatemala Rhubarb	1,5m	
Turneria ulmifolia	Yellow Adler	1m	

Some Ornamental Plants

Agave spec.			evergreen		succulent
Albizia lebbeck	Mother-In-Law	8m			tree
Aloe spec.		small	evergreen		succulent
Bambusa ventricosa	Buddhas belly bamboo	4m	evergreen		shrub
Bauhinia wallichii			evergreen		shrub
Bougainvillea varities	Bougainville	4-5m		armed	shrub
Cassia auriculata		1m	indigenous		shrub
Clitoria ternatea	Butterfly Bean			slender vine	
Delonix regia	Flamboyant	12m	deciduous		tree
Filicium decipiens	Fern-leaf Tree	4m	indigenous, evergreen		tree
Hibiscus rosa-sinensis		3m			shrub
Jasminum varities		small			Shrub
Kalanchoe pinnata		small			shrub
Lagerstroemia indica	Crape Myrtle	4-5m	deciduous		tree
Pandanus kaida	Wetakeiya		indigenous		shrub
Plumeria alba	Temple Tree, Pagoda Tree		deciduous		tree
Plumeria lutea	Temple Tree, Pagoda Tree		deciduous		tree
Plumeria obtusa	Temple Tree, Pagoda Tree	5m	deciduous		tree
Plumeria rubra	Temple Tree, Pagoda Tree		deciduous		tree
Polyalthia longifolia var. pend.	Indian Willow	15m	evergreen	Pillarshape	tree
Sansevieria varities	Spearagave	small			
Spathodaea campanulata	African Tulip Tree	15-			

		12m			
Tecoma stans		5m	deciduous		shrub
Thevetia variegata	Ponnaleri	4m	evergreen		
Yucca varities					

Fruit Trees

Aegle marmelos	Golden Apple	3m	indigenous	armed
Anacardium occidentale	Cashewnut	8m	semi-evergreen	
Artocarpus heterophyllus	Jackfruit	10-20m	indigenous	
Mangifera indica	Mango	30m	indigenous, evergreen	
Manilkara hexandra	Wild Chico	8-10m	indigenous, evergreen	
Psidium guajava	Guava	10m	indigenous, deciduous	
Punica granatum	Pomegranate	3-5m	deciduous	

Hedges

Allamanda cathartica	Golden Trumpet	sun		
Atalantia monophylla	Wild Citrus	shade	evergreen	armed
Bougainvillea spec.				
Capparis brevispina		sun		
Capparis sepiaria	Hedge Caper			
Carissa spinarum		sun		
Cassia spectabilis		5m	deciduous	
Clerodendrum inerme	Forest jasmine	3m	indigenous, evergreen	
Joddalia asiatica		shade		
Pleiospermum alatum		sun		
Thespesia populnea	Tulip Tree	8m	indigenous, semi-evergreen	
Ziziphus oenoplia				

Groundcover

Clematis triloba	Deccan Clematis			
Crassula arborescens	Jade	0,5m		
Cymbopogon citratus	Lemongras		indigenous	
Cyperus pygmaeus	Cyperaceae			
Heteropogon contortus	Gramineae			
Jasminum angustifolium			indigenous, evergreen	
Jatropha curcas	Kattamanekku			
Mimosa pudica	Sensitive Plant			thorny creeper
Ruellia tuberosa	Meadow-weed			
Sansevieria roxburghiana	Indian bowstring hemp	0,3m		
Vernonia eleagnaefolia				creeper

Large Trees For Canyons

Vitex leucoxylon		deciduous, up to20m	
Strychnos nux-vomica	Strychnine Tree	semi-evergreen, up to 15m, indigenous	
Terminalia arjuna	Arjuna	semi-evergreen, up to 20m, indigenous	

Medium Sized Trees For Canyons

Alangium salvifolium		evergreen, up to 10m	
Barringtonia acutangula		evergreen, up to 8m	
Mitragyna parviflora		semi-evergreen, up to 6m	
Pongamia pinnata	Indian Beech	semi-evergreen, up to 10m	

Small Trees For Canyons

Commiphora caudata		6m	
Suregada angustifolia		3m	

Shrubs For Canyons

Ochna obtusata	Bird's Eyes Bush	4m	indigenous, deciduous
Helicteres isora	Valempuri	2m	indigenous, deciduous

Pioneer Plants (fast growing)

Acacia auriculiformis	Ear Pod Wattle	10m	
Acacia holosericea	Wah-roon		
Acacia mangium			
Borassus flabellifer	Toddy Palm, Plamyra Palm		indigenous
Bougainvillea varities	Bougainville	4-5m	
Calotropis gigantea	Crown plant	2m	indigenous, evergreen
Caryota urens	Fish Tail Palm		indigenous
Khaya senegalensis	African Mahagony		
Premna tomentosa		3m	semi-evergreen

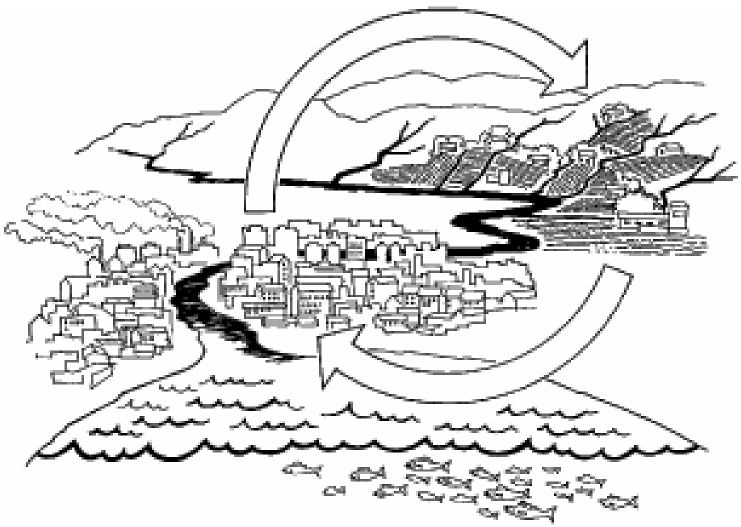
(*1 *ngamia pinnata* -	plants which are used more often)
(*2 *Commiphora caudata* -	more rare plants)

Sanitation concepts

A. Introduction

There is a lot of strong criticism about conventional sanitation concepts including: The misuse of precious freshwater just for transporting human excrement, the increasing initial investment, the high operating and maintenance costs, the water pollution, the hazardous substances sprayed around, pathogens etc. and the loss of nutrients and trace elements contained in excrement through discharge into water.

Due to the paradoxes and the disadvantages of conventional sanitation concepts, a development process began which acknowledges the ‘end-of-the pipe technology’ to a closed loop approach for sustainable wastewater management. Key features of this natural oriented approach include: closing of material cycles, recovery and re-utilization of nutrients, optimizing of water consumption, treatment of human excreta as a resource rather than waste, reduction of energy consumption as well as the production of energy through biogas, and the minimization of health risks and hygienic problems.



Definitively a break-through in the paradigm of water usage and sanitation, we consider it as one of the most promising directions to deal with water in a constructive way.

Wastewater treatment system is adressed in an other part of this document.

B. Wet or Dry Ecological Sanitation (to mix or not to mix?)

How much potential has the WC? A massive stream of food (nutrients) from the rural areas to the cites is impoverishing the soil in the rural areas, and threatening the health of both urban and rural populations. Urban growth has created sewage systems which pollute rivers and lakes. Even the oceans are at risk because of the popularity of flush water toilets. The challenge is to create a corresponding stream of nutrients back to the productive soil without creating new problems.

The great success in sanitation was the introduction of the water toilet. Urban fecal born diseases were reduced to fractions of what the problem was before the introduction of waterborne sanitation. The WC became a reality, or a dream, for the entire urban population, worldwide.

Why did the WC become so popular? Because of its excellent hygiene? No. It is because of the rapid "elimination", out of view, of that unpleasant matter that had to leave the body. Municipalities had to spend more and more money to extend the necessary sewers until they reached the "final" destination, a nearby river where the untouchable excrements became invisible — but not harmless.

For low income populations, conventional dry latrines are the most common type of sanitation. It has the advantage of not polluting the streams and the impact on the ground water is less than, for example, WCs with conventional septic tanks. It also bears its own costs, as the municipality normally does not subsidize construction. Still, it does not return the fertile value of the food to the plants. Only a fraction may be found by roots of trees and returned to nature and men in terms of cleaner air, shade and beauty. — For sustainable ecological development we need new ecological solutions.

Ecologically, we are getting poorer and poorer as we are wasting our waste. In the long term, there is a need for some way to return the nutritional value from the human waste to the soil. There are principally two solutions: Dry ecological latrines, or wet flush toilets with ecological treatment. The two systems have advantages and disadvantages, possibly making them suitable for different areas. Eventually, an ecological sanitation system for urban areas will need some sort of transport facility, returning the nutritive value to nature.

Dry systems may include urine diversion, where the urine can be stored in separate tanks and taken to rural areas to be used as fertilizers. Urine is normally safe but unpleasant to handle. The fecal matter can be treated locally or centrally. In its fresh form it is dangerous to handle and local treatment with ash or lime can not always be trusted. With a wet system you flush and the system takes over. — Good or bad?

Should we choose a dry system, which would save a lot of water, or a waterborne system, which seems to be much easier for people to accept?

1. Wet ecological sanitation

Low water flushed latrines can become ecologically sound. The water can be filtered through ecological wetlands for compost and energy production before it is used as irrigation for fruit trees and possibly other products.

2. Dry ecological sanitation

Dry ecological latrines will produce two products, the urine, which is rich in nutrients and (microbiologically) sufficiently safe for immediate use as a fertilizer, and the fecal matter which either should be burnt in the toilet (incineration toilets) or treated and used as compost. In the International Zone the demand for fertilizers (urine and compost are fertilizers) will be important because of the large proportion of non built-up area. Anyhow, the handling of urine (storage and transport) can become difficult if not well organized. On site treatment is difficult to control and the microbiological quality of the human waste may be doubtful.

3. A way forward?

Waterborne systems require water, which is a limited resource. Ecological treatment can be made locally with solids separation and drain fields (sub-surface irrigation with evapo-transpiration beds) or in treatment plants. Recent developments of flushing systems have reduced the water demand to the point of ecological soundness. A one liter flush dilutes the urine to the concentration the plants like. With ecological treatment of the sullage we no longer waste the water; we return it to nature as a fertilizer.

C. Some Basics on Sanitation

Sanitation is the prevention of the sporadic outbreak of diseases dangerous for the general health of the public. This can be achieved by either controlling or eliminating such environmental factors as contribute in some form or the other to the transmission of the diseases. These factors include the following

- Water supply.
- Carriage or disposal of human excreta and other wastes from communities, industries and trades.
- The menace of insects-mosquitoes, flies and rodents with regards to food and other services.
- Ventilation and air-conditioning.
- Atmospheric pollution and method of purification.
- Plumbing in the case of building
- Other hygienic factors.

Sanitation, in short, is a public health work.

1. Sewage, Sewer and Sewerage.

Sewage may be defined as the used water or liquid waste of a community, including human and household wastes together (or not) with street-washings, industrial wastes and such ground and storm water as may be mixed with it. A sewer is an underground conduit used for the removal of sewage and sewerage is the general process of removing sewage. The entire system of conduits and appurtenances involved is called a sewerage system or sewer system.

The constituents of sewage are:

- Domestic sewage, which includes human excreta as well as discharges from kitchens, baths, lavatories etc, from public and private buildings;
- Industrial and trade-wastes from manufacturing processes such as tanneries, slaughter-houses, distilleries, mills, laundries, chemical plants, etc;
- Ground water or subsoil water entering sewers through leaks;
- Storm water which is rain water from houses, roads, along with surface water etc. if not taken care of separately.

2. Sewage Treatment and Disposal.

From the public health point of view it is important that the sewage as and when collected should be promptly disposed of without causing any nuisance whatsoever.

Sewage is ultimately disposed of either on land or in water. But before that a certain amount of treatment would be necessary in order to make it harmless. When disposed on land, methods adopted should be such that sewage does not result in breeding mosquitoes or flies or spreading disease. If close to dwellings, odors may have to be well controlled too. When disposed of in running waters, sewage should not result in any pollution of water to more than a permissible level, in case this same water is to be later used as a source of public water supply, nor should it destroy the fish or aquatic life inside the water.

In treatment, sewage is split up into solid, liquid and gas. The semi-solid part called sludge may be dried, buried, burnt or composted and then more positively used as a fertilizer. The liquid portion may be used in the development of sewage-farms or irrigation project, whereas the gases (methane, etc.) may be used for heating or generating power in gas-engines, etc. which, therefore, would bring in assorted financial returns. The economic aspect, however, is of secondary consideration. The first and foremost consideration is the disposal of sewage without nuisance or danger to public health.

3. Methods of Collection

1. The Dry or Conservancy System of Collection

It is the earliest method and even now practiced in unsewered areas. This consists of the accumulation of night soil or human excreta in latrines or privies, cesspools, etc., and its subsequent removal manually and transport in vehicles to points of ultimate disposal. The waste water from kitchens, baths, etc. called sullage and the storm water are collected separately in gutters and led off into neighboring drainage channels, rivers etc. for disposal.

2. The Water-carriage System.

In this system, the night soil gets mixed up with a sufficient quantity of waste water, forming sewage, and is collected in a system of pipes and transported for subsequent treatment and disposal in a harmless manner without any nuisance. As the dilution of the solid matter in water to form sewage is normally very great (sewage is known to consist as much as 99.9 percent by weight of water and only 0.1 percent of solid matter), sewage easily flows in accordance with the laws of hydraulics as applied to the flow of water.

Furthermore, in a combined system, the same sewer is intended to carry the domestic sewage and industrial wastes as well as the surface and the storm water flow.

In a separate system, the domestic sewage and industrial wastes are carried in one set of sewers, whereas the storm and surface waters are carried in another set of sewers.

A partially separate system is a modification of the separate system in which the separate sewer, discharging domestic sewage and industrial wastes also contains a portion of the surface water drained from paved backyards and the roofs of houses.

4. Conclusion

The modern trend is towards the adoption of a separate system. The following three arguments are mainly advanced in favor of adoption of this separate system:

- The length of sewers with a large diameter is decreased as there are two sets of sewers.
- The storm water is disposed of in natural areas and is not carried to the treatment system. Thus, the load on the treatment system is decreased when a separate system is adopted.
- When a separate system is adopted, the sanitary sewers can be designed for the maximum rate of sewage. Such a design will develop a self-cleansing velocity which will keep the sewers clean. In case of a combined system, the self-cleansing velocity is developed only at the time of a storm. There are thus chances for combined sewers to be easily silted and they become foul in dry weather.

It is true that the water carriage system has become the universal technique of collection and transport of a community's domestic or sanitary waste. But the irony lays in the fact that the system generates liquid wastes nearly 100 times the volume of the actual domestic waste products in order to transport from closed conduits or sewers to the final point of disposal. Thus, the water carriage system generates enormous quantities of waste having a high pollution potential. It also ultimately leads to the pollution of land and water resources.[20]

The use of filtered, processed water for flushing toilets and cleaning small sewer lines is appreciably high. For instance, a typical flush toilet will contaminate each year about 60,000 liters of fresh water to move a mere 800 liters of body waste. Thus, the valuable fresh water is mixed with body wastes having high fertilizing potential and then we pay dearly to separate them again. The load on the treatment plant, pumping station, etc. is increased and it results in a high investment and recurring costs. It is therefore quite likely that in the future, the possible alternatives of the water carriage system may be thought of, such as decentralized treatment and disposal, on-site treatment and disposal system, conveying system requiring less quantity of water for its functioning, etc.

While the Dry System practice seems to belong to the past and the Water Carriage is the so-called modern way, decentralized wastewater treatment techniques and moreover the newly emerging concept of Eco-sanitation, together with appropriate storm water management, are exchanging this view for a more sustainable and affordable one:

- It is questioning the very need for a sewer to carry wastewater.
- It is looking at wastewater not as a nuisance to eliminate from our surrounding, but as a potentially valuable back product of any human activities.
- It is finally offering, with the help of appropriate changes, a really positive, cycle-oriented solution.

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[20] RANGWALA – Water Supply and Sanitary Engineering

D. What can be gained out of Wastewater?

In the following part the concept of eco-san will be presented. The reader will get a survey about the latest available technology including their advantages/disadvantages. Potential health risks and opportunities to minimize these will be also discussed. Furthermore, a framework for applying an eco-san approach according to local circumstances will be presented.

In the natural world, excreta from humans played an essential role in building healthy soils and providing valuable nutrients for plants.

Agreement Signed to Build China's First Ecosan Town

On Sept 23, 2003 an agreement was signed in Dong Sheng between Stockholm Environment Institute (EcoSanRes) and City of Dong Sheng (Erdos Municipality) to build an eco-town using the principles of ecological sanitation, the first of its kind in China.

The Erdos eco-town is a pilot project being sponsored by the Dong Sheng District and the Swedish International Development Agency will be built over the next three years with completion in 2007. It will comprise 1500 dwellings in 4-, 2- and 1-story buildings in the Hei Zao Kui area of Dong Sheng in Inner Mongolia (Northern China).

This part of China is drought ridden receiving 300-400 mm of precipitation per year. Cities are required to ration water and most residents have no private sanitary services. Conventional solutions to urban sewage collection and treatment are thus inadequate here and alternative methods are necessary.

The eco-town will be set up with modern urine-diverting toilets, one in each dwelling and grey water from the kitchen and bath will be collected and treated separately using soil filtration and a constructed wetland. Storm water will not be mixed with any household water. An ecostation will be built to collect the various household products that will be recycled, i.e. urine (encompasses 80% of the nutrients leaving the human body and an excellent fertiliser supplement), sterilised faeces (soil conditioner) and Organic kitchen wastes which will be composted and solid wastes which will be source-separated.

The eco-town will be at the beginning a large R and D effort to further develop and standardise the various urban ecosan applications. Rural ecosan has already taken off in a big way in China with some 100,000 urine-diverting dry toilets installed over the last few years. Urban ecosan has been tested in a few housing complexes in Sweden over the past 5-10 years. This collaboration with China represents a breakthrough that will provide opportunities for many urban centres around the world to learn from.

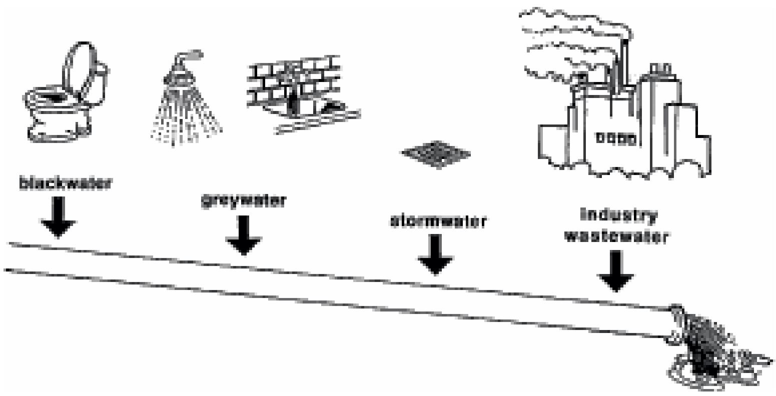
For more information contact EcoSanRes

In contrast to conventional approaches, the 'eco-san' concept does not break this cycle. Eco-san treats human excreta as a sustainable resource and, therefore, the need for chemical fertilizers is reduced.

"Ecosan is not a specific technology,

it is more a philosophy!" [21]

Over a year, each person produces some 400-500 liters of urine and 50 liters of feces. This could contain enough nutrients to grow up to 230 kg vegetables. Usually this amount of excreta is flushed away with 15,000 liters of pure water[22]. With a daily freshwater need of 3 liters it is possible to ensure the water needs for one human for nearly 14 years via a pipe system capturing the bath, kitchen and laundry water, often called, grey water. This may add up to another 15 - 30,000 liters for each person every year, which is enough to supply drinking water for 27 people for one year or 10,000 people for one day.



If we do not change, we will not be able to provide for the needs of the present generation without hindering that of future generations. Thus, sanitation approaches must be resource minded, not waste minded. Continuing with the conventional sanitation concepts is neither practical nor suitable for a city of the future. Therefore the author will describe present concrete opportunities to deal in a sustainable way with water.

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21 Eco-San Presentation, 2003, Bangalore

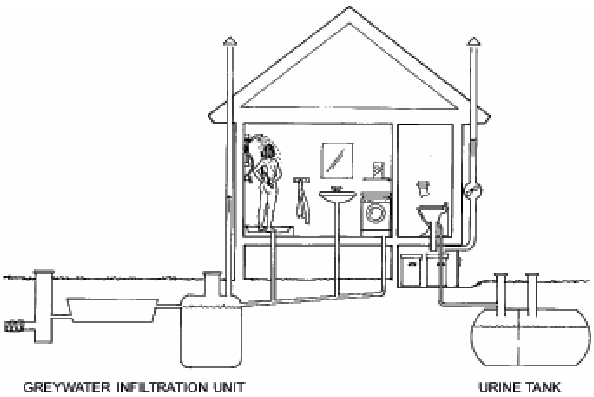
22 Esrey, A. et al. 1998 "Ecological Sanitation" Swedish International Development Cooperation Agency Stockholm (Sida)

1. Grey water

The water generated from food preparation, bathing and washing is known as grey water. Dry sanitation systems do not handle grey water and therefore a separate system must be devised to take care of this potential resource. Both the quantity and the quality of grey water can be controlled at the household level. Any strategy for managing grey water can be made easier by water conservation measures as well as attention to the soaps, cleansers and other household chemicals used.

The amount of grey water generated can be significantly reduced through behavioral changes, good maintenance of pipe and water taps, and by the use of water-saving devices. To the extent that pollutants in grey water are a problem, it makes sense to prevent them at the source by selecting non-polluting household products.

Grey water irrigation can be as simple as pouring it on garden areas by hand. Using grey water for plant irrigation is often the easiest way to recycle it. In many parts of the world where water is scarce, this is done as a matter of course. Although it does not generally present health concerns and will not pose significant pollution hazards, it is better if organic, non-toxic products are used for washing and cleaning. It is best to design a grey water system that prevents human contact and the potential for environmental contamination. But even where management consists of using it to water plants, or simply allowing it to infiltrate the soil, the hazards posed by grey water are far less than those posed by human excreta or the lack of good hygiene.



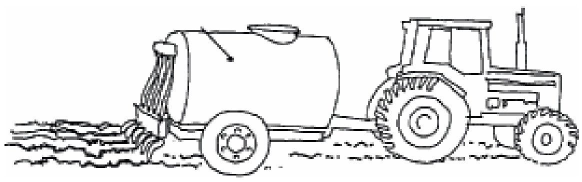
(Figure: house in Sweden with a dehydrating toilet, urine diversion and storage in an underground tank and on-site grey water treatment.)

2. Black water: a plant nutrient resource

Most of the plant nutrients in wastewater originate from urine and feces. By diverting the black water from the grey water, 80-95% of the plant nutrients (nitrogen, phosphorous and potassium) in the household sewage water are recovered. These are considered pollutants when discharged into water. Consequently, the pollutant discharge from the household is decreased by the same amount. Furthermore, the discharge of pathogens is decreased, as the main source of bacteria, viruses and parasites is the feces.

3. Yellow Water

Separated urine is called yellow water. Roughly 65 to 90 % of the excreted nitrogen, phosphorus and potassium are found in it. Furthermore, plant nutrients excreted in urine are found in chemical compounds that are easily accessible for plants. Initially 80-90 % of the nitrogen is found as urea, which rapidly degrades to ammonium and carbon dioxide, while the phosphorus and potassium are in the form of phosphates and ions respectively. Many chemical fertilizers contain, or dissolve to, nitrogen in the form of ammonium, phosphorus in the form of phosphates, and potassium in the form of ions. Thus, the fertilizing effect of urine ought to be comparable to the application of the same amount of plant nutrients in the form of chemical fertilizers[23].



[23] Jönsson, H (1997). *Assessment of sanitation systems and reuse urine*. Sida Sanitation Workshop, Balingsholm, Sweden.

E. How to reduce Wastewater generation?

1. Water Flushed Toilets with Gravity Sewers

The water-flushed toilets with gravity sewers are often constructed with a cleverly designed trap, which results in a very low flush water volume. This means that the requirements for the slope, length and material of the sewage pipes are especially strict. The space between toilet and tank should generally not be more than 20 m. otherwise some kind of pump is required.

2. Extremely Low Flush Toilets[24]:

One major factor of water consumption is the flush water used for toilet purposes. A conventional toilet flushes between 6 – 12 l each use through the pipe. It is proposed that one day there will be 7,000 people working in the IZ and about 3000 visitors passing through it[25]. If each of them would just use the toilet once a day, there would be a total consumption of about 90,000 l/d. This unnecessary waste of mostly fresh water can be extremely reduced through using alternative technology.

On the other hand, the volume of urine and feces due to mixing with fresh water is enormously increased. Usually, the nutrient-rich backwater which also contains most of the infectious matter is stored in tanks. Therefore, another advantage is that lower flush water volume requires fewer loads, less transport and less storage capacity.

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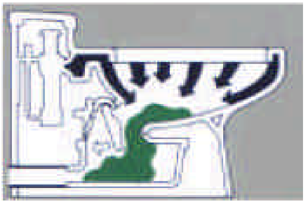
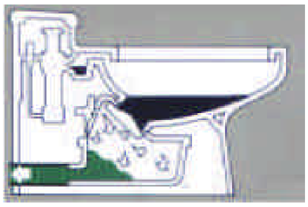
[24] af Petersens,E. et al, 2001 "Marked survey, extremely low flush toilets"
[25] Helmut, 2002 "The hole about the IZ"

3. Vacuum-Flushed Toilets

The vacuum-flushed toilets are based on a non-water transportation system; water is only used for rinsing the toilet bowl. The pressure in the pipes is created by means of vacuum pumps, ejectors or compressors. The vacuum toilets are designed for larger systems such as multi-story buildings, schools etc. A vacuum system requires airtight pipes. There are no requirements for slopes or length of the sewage pipes. A vacuum system is dependent on electricity and can be relatively expensive to install. The systems require regular service, in many cases by a professional.

4. Urine Diverting Toilets

The urine diverting toilets have two bowls and/or two outlets, and two different flush water volumes for the “small” and the “large” flush. A urine-diverting toilet where the large flush is used only at one out of six toilet visits uses much less water than a conventional low flushing toilet and offers the separated treatment of yellow and black water.

5. Urinals

Urinals have many advantages – they reduce the amount of water, take up less space than water closets and are easy to clean. In the same way as urine diverting toilets, by combining conventional toilets with urinals, it is possible to reduce the number of “large” flushes. Therefore, urinals are a good complement to low flush toilets in sports halls, schools, public lavatories, etc. However, urinals are still primarily useful for men.

A new generation of urinals is on the market. These urinals do not use any water for flushing! It is entirely based on gravity. The urine passes through a stench lock with a sealing liquid that works as a stench barrier. The urine, which is heavier than the liquid, sinks down through the liquid and further down the drain. If the yellow water is spread on agricultural fields it is necessary to use only biologically degradable barrier liquid.

6. Dry Sanitation with Reuse of Waste

The practice of reusing human wastes is not new. Although the relationship between human feces and disease was not yet understood, the value of human feces as a fertilizer was known in Syria over 1000 years ago.

Dry sanitation is the disposal of human urine and feces without the use of water as a carrier. The nutrients contained in the excreta are then recycled by using them as soil conditioner or fertilizer in agriculture. Human excreta are processed on site and then,

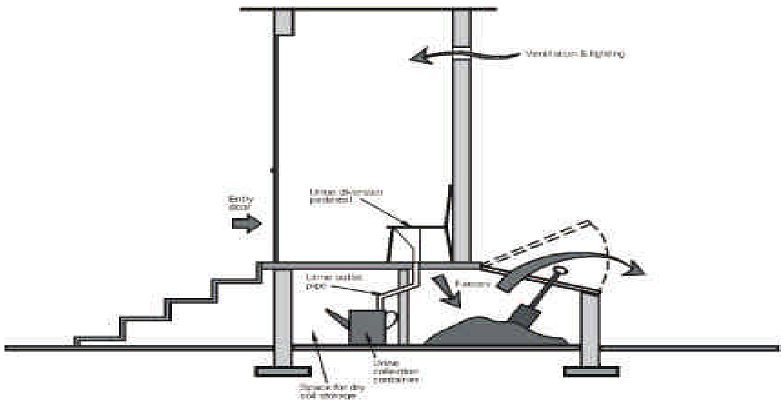
if necessary, further processed off site until they are completely free of disease organisms. In addition, dry sanitation wastes no precious freshwater to dispose the excreta. Therefore, dry sanitation could be a valid alternative to water based sanitation, but reuse of the contents of dry sanitation systems offers both advantages and risks.

There are two main processes employed in dry sanitation reuse.

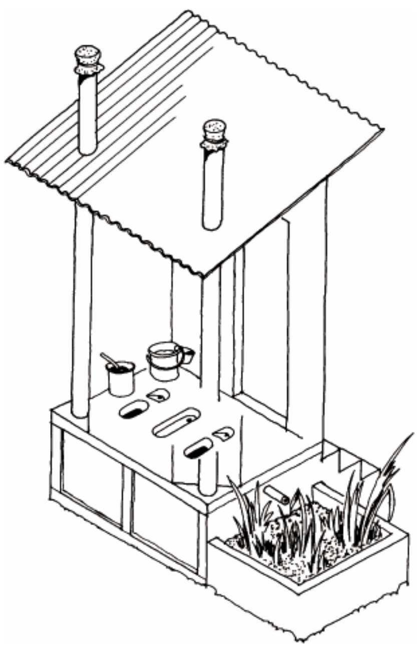
1. Decomposition (Composting)

Toilets based on the process of biological decomposition use bacteria, worms or other organisms to break down the feces, producing compost. The temperature and airflow are important parameters in such designs. It is important that airflow is sufficient to maintain aerobic conditions in the feces pile. Urine is not usually diverted. The end-product is fine compost that can be used as a soil conditioner.

The additional liquid produced is either evaporated or is allowed to flow into an evapo-transpiration reed bed next to the toilet which fits very well to the Indian habit of being ‘washers’. Adding lime, ash or wood shavings is a good method to control smell and fly breeding.



2. Dehydration



When something is dehydrated all the water is removed from it; therefore, toilets based on the process of dehydration do not generally mix the feces and urine. The urine is diverted and either collected or flows into a soak-pit. The feces are collected in one of two chambers below the toilet seat. After each defecation lime, ash, or earth is added to dry the feces. If the moisture content below is 25% there is rapid pathogen destruction, no smell, and no fly breeding. The greatest risk of failure with a sanitation system based on dehydration is wetness. By adding a simple solar heater to the processing vault, this risk can be reduced.

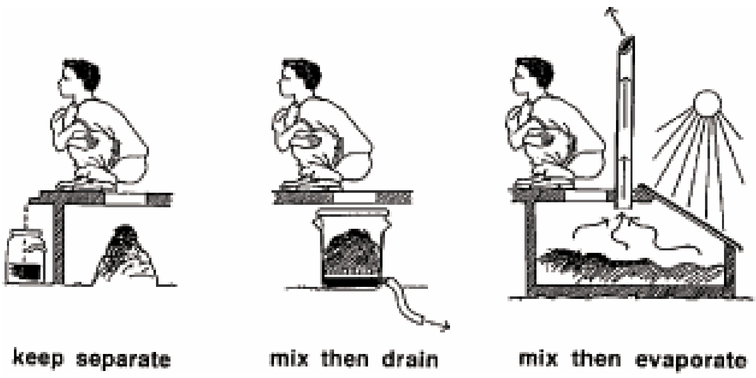
3. Decomposition vs. Dehydration

In a well working decomposition process the organic substances are turned into humus. Therefore, the process ideally requires humidity around 60 % and a carbon to nitrogen ratio of about 30:1. If these circumstances are not guaranteed the process slows down or stops. Further, in practice it is difficult to reach a temperature <60°C and, therefore, the effective destruction of pathogens is guaranteed with a retention time between 8-12 month. As well, toilet-paper usage is no problem and even water used for anal cleaning or mix of urine and feces is easy to manage.

Dehydration is an effective way of destroying pathogenic organism. There is no fly-breeding and low odor usually due to the low humidity. Otherwise, it requires a diversion of urine and anal-cleaning water. Regardless of the storage time, toilet-paper or other things placed into it, the processing vault will not disintegrate.

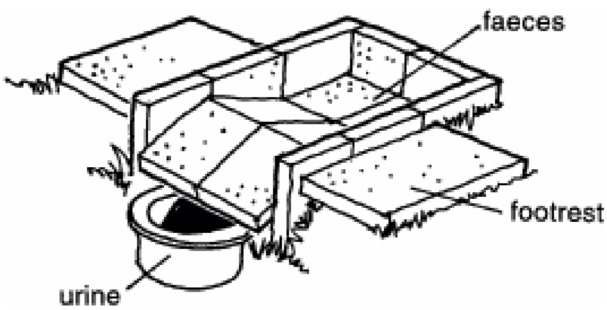
4. Dealing with Liquids

Shivambu – "*the water of Shiva*" or *"the drinking of water of happiness".* Urine's incredible positive effects are known and used by millions of people. To lose fear about one's urine, one should know that nothing comes out, which has not been inside before. Each one of us swam in our own urine for about nine months in the *amniotic sac*.



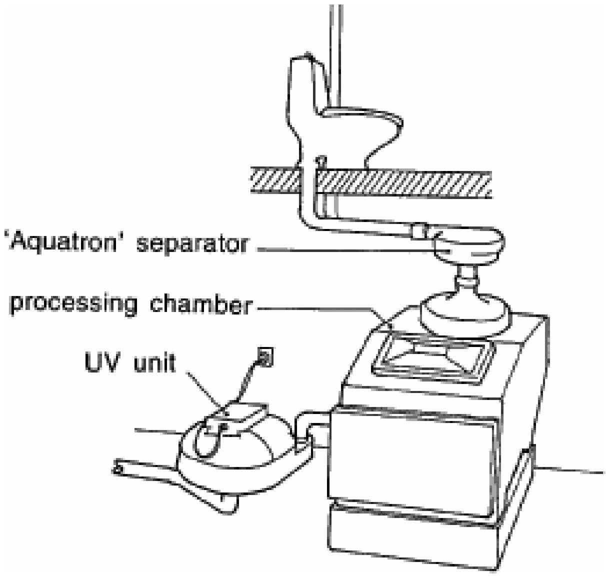
a) Liquid Diversion

There are at least three good reasons for not mixing urine and feces: it is easier to avoid excess humidity/wetness in the processing vault, the urine remains relatively free from pathogenic organisms in the processing vault, and the uncontaminated urine is an excellent fertilizer. The problem is that urine diversion requires a specially designed seat-riser or squatting slab that is functionally reliable and socially acceptable.



b) Liquid Separation

Systems based on liquid separation do not require a special design of the seat-riser or squatting plate. Urine, feces, and in some systems a small amount of water, go down the same hole. Liquids and solids are then separated. As the liquids have been in



contact with feces they must be sterilized or otherwise treated before they can be recycled as fertilizer. This requires an appropriate technique which is comparably expensive.

5. Health Risks

a) Feces

The isolation, reduction and/or elimination of pathogens (disease-causing organisms) are the primary objectives of any sanitation system to maintain human health. There is a general agreement among dry sanitation promoters that a risk to health may exist if such systems are not properly operated[26]. The amount of treatment required is dependant on the health status of the user and the final reuse of the end-product. It has been suggested that primary treatment either by dehydration or decomposition is usually sufficient to destroy most pathogenic organisms, but secondary treatment (for example high-temperature composting) may be required where intestinal parasites are common[27].

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26 Anne Peasey, "Health aspects of dry sanitation with waste reuse" Page 27

27 Winblad, U. 1996. "Towards an ecological approach to sanitation". Paper presented at the Japan Toilet Association Symposium in Toyama, Japan, October 1996.

Unfortunately, over one-third of the population in developing countries is infected with intestinal worms, of which a large proportion is children[28].

Due to the expositional character of the IZ and the fluctuation of people, it is inevitable that there will be users with parasites. Therefore, a secondary treatment is recommendable. Additionally, a greater understanding of pathogen die-off during the ordinary use of these technologies is required.

b) Urine

Urine contains few pathogens; however, it may contain Ascaris eggs and Schistosoma eggs[29]. Urine may also carry the pathogens responsible for typhoid. Fecal contamination of the urine can occasionally occur when the user has diarrhea, by mistake, or by children who often find it difficult to correctly use the urine-separator. In view of this, Drangert (1998) recommended storing urine for six months prior to use on the vegetable plot. There is clearly a potential risk from the re-use of urine. Therefore, storage of urine for 6 months should be sufficient to eliminate all pathogens. Results indicated that at ambient temperatures of 2?C or more, pathogen die-off is more rapid. However, the author suggested caution, since the studies did not take into account parasites prevalent in tropical conditions nor vibrios, such as *Vibrio cholera* that may have extended survival at high pH values. Also to eliminate risks from viral pathogens such as rotavirus would require storage for 4-5 months at 2?C.

6. Advantages & Disadvantages of Dry Sanitation

a) Advantages

- **Water requirements:** No water is required to flush away the human waste
- **Construction:** When constructed from local materials, the construction is simple and does not require skilled labor
- **Spread of disease:** Unlike conventional pit latrines, fecal material is isolated from the groundwater table. The end-products have minimal concentrations of fecal pathogens. No smell. Does not encourage fly breeding

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28 Chan, M.S. 1997. "The Global Burden of Intestinal Nematode Infections" - Fifty Years On. Parasitology Today 13(11), 438-443.

29 Drangert, J. 1998. "Fighting the urine blindness to provide more sanitation options".

- **Environmental contamination:** Raised chambers with concrete bases for storing the excreta avoids contamination of soil, rivers and groundwater
- **Environmental sustainability:** End-product from the feces pile can be used as a soil conditioner. The urine can be diluted and used as a source of nitrogen for plants.
- **Community acceptance:** Women when defecating often preferred sitting (on the toilet) rather than squatting (open defecation)

b) Disadvantages

- **Usage:** More sensitive to misuse than other forms of sanitation. Keeping the urine separator and pipe clean to avoid odors may be a problem.
- **Spread of disease:** Incorrect usage and maintenance can result in pathogens surviving in the end-product from the feces pile. If storage time of the pile is too short, pathogens may still be viable. There is a small risk to health from the use of the urine, through contamination of the urine with feces or if the one excreting has Ascaris or schistosomiasis.
- **Community acceptance:** For urine diversion to work, men must sit to urinate, which is often unpopular. In cultures where water is used for anal cleansing, separate arrangements are required to keep the chamber dry

7. Parameters to Consider Before Implementing Dry Sanitation

Ideally, an eco-san system will prevent pollution, sanitize excretal nutrients and return them to the soil and require no water for transport or processing. This chapter has presented a number of examples of different design strategies for eco-san systems. However, each of these systems is developed to address those issues that are of greatest concern in the place where they are used. In response to local circumstances the following points provide a framework for the thinking of applying an eco-san approach. Many local variables influence the choice of an appropriate sanitation system:

- **Climate:** Temperature, humidity and rainfall
- **Topography and soil type***:* infiltration rate (how quickly and in which direction water and pollutants move through soils)

- **Scarcity of water: The relative importance of water conservation.**
- **Proximity/sensitivity of water resources and aquatic ecosystems:** Groundwater level and availability; closeness to lakes, rivers and streams, or coastal waters.
- **Energy:** The availability and the durability of local energy inputs and renewable energy systems such as solar radiation or wind turbines
- **Social/cultural:** The customs, beliefs, values and practices that influence the design of the 'social' components of a sanitation system, its acceptability or 'fit' within a community.
- **Economic:** The financial resources of both individuals and the community as a whole to support a sanitation system.
- **Technical capacity:** the level of technology that can be supported by local skills and tools.
- **Infrastructure:** The existing level of both physical infrastructure and existing services that might help support a sanitation system (i.e. extent of existing water supply, transport, public health network, educational system etc.).
- **Population density and settlement pattern:** The availability of space for on-site processing, storage and local recycling.
- **Agriculture:** The characteristics of local agriculture and home gardening

8. Dry Sanitation in Auroville

During the last couple of years, a few tentative examples of dry sanitation have been developed.

One of them lies in the middle of the International Zone, with the U.S. Pavilion Student's Hostel. This building is also equipped with a rainwater harvesting system.

7. In-House Water Saving Devices

It would be the "lions way" if humans would appreciate water so much, that they would feel pain while wasting water. It is at least necessary to make people aware of the effects of their own water-use and encourage them to appreciate this precious resource.

But still it is possible to make people save water, even without their own resolve. It is then mainly a matter of design and must therefore be integrated at the conceptual stage.

There are some smart techniques which are listed below[30].

- **Faucet aerators:** increases the rinsing power of water by adding air and concentrating flow, thus reducing the amount of water used
- **Limiting-flow shower heads:** Restricts and concentrates water passage by means of orifices that limit and divert shower flow for optimum use by the bather
- **Pressure reducing valve:** Maintains home water pressure at a lower level than that of the water distribution system; decreases the probability of leaks and dripping faucets
- **Toilet leak detectors:** Tablets that dissolve in the water closet and release dye to indicate leakage of the flush toilet
- **Water efficient clothes washer:** Reduce the water used
- **Water efficient dishwasher:** Reduce the water used

F. Some understanding

While presenting the pros and cons of water saving techniques, it may be good to come to figures to understand the value of such a suggestion.

The following table is based on the average daily consumption for domestic use in Auroville, this without irrigation. Details are estimated form other sources, nothing as accurate being available from Auroville itself yet. The domestic consumption in Auroville is fluctuating today from 115lcd to 330lcd, but we cannot yet calculate if the higher values are purely without irrigation.

30 Metcalf & Eddy, Wastewater Engineering ,3rd edition

By comparison, the average consumption in France is 150lcd, and 158lcd in Switzerland. In India, it is estimated to be 135lcd. The city of Bangalore, the IT city of India, which should therefore show a high life standard, has a consumption of 135lcd, including garden irrigation!

Keeping this in mind, the soundness of the thinking reflected herewith is clear, while to extrapolate global water consumption for the International Zone out of it is not realistic because of too many unknown factors, starting with the activities in the area.

Potential Evolution of Domestic Water Consumption per capita in Auroville

	Actual Water Consumption l/c/d	Reusable part	Consolidated consumption with flow saving devices l/c/d	Reusable part	Consolidated Consumption with Combined Systems		Reusable part	With ecological sanitation		Reusable part
					Groundwater water l/c/d	Rainwater l/c/d		Groundwater water l/c/d	Rainwater l/c/d	
Bathing	60	60	42	42	42		42	42		42
Cleaning of House	10	0	9	0		9	0		9	0
Cooking	7	0	7	0	7		0	7		0
Drinking	3	0	4	0	4		0	4		0
Flushing of Latrine	30	30	23	23		23	23		3	0
Washing of Clothes	60	60	20	20		20	20		20	20
Washing of Ustensils	15	15	12	12	12		12	12		12
Total	**185**	**165**	**117**	**97**	**65**	**52**	**97**	**65**	**32**	**74**
Proportion	100%	89%	63%	83%	35%	28%	83%	66%	33%	76%

Anyhow, by looking at the probable high needs of public toilets facilities, the above reflection makes complete sense.

By looking at the values, the valuable cost effectiveness of water saving techniques, including rainwater recycling, on wastewater treatment facilities cannot be neglected.

If all the rainwater falling on all the roofs of the International Zone were to be collected, it represents a total average yearly volume of 158,509m2 (Source Helmut 11-03-2002) x 0.864m = 136,952m3. Following the projected population of 3,000 residents and about 7,000 visitors per day, a first evaluation shows that harvestable rainwater should well meet the demand.

The remaining question therefore is: is it affordable?

G. Recommendations

Dry Sanitation Toilets are more sensitive to misuse than other forms of sanitation. Therefore, an appropriate maintenance and user awareness is required. A common problem is that no one takes clear responsibility for public toilets. When there is low user awareness, decomposition is recommended because there is no need to separate the urine from the feces. Also, a mix of low flush and dry sanitation concepts should be considered.

Due to the single occurring runoff, public toilets have to be localized in an area fairly remote from the natural drains. The ground water also has to be protected from fecal contamination.

Furthermore, it is absolutely necessary to design dry toilets in an “attractive way”. The user should not feel uncomfortable while using them and it should not expect too much of the user. Simple, clear, understandable drawings will help people to use them in the right way.

Vacuum toilets require high maintenance service and dependable electricity. The actual situation of weekly power cuts and poor level of professional maintenance does not make this technique effective yet. But, the usage should be reconsidered if the situation changes as they offer an odor-free and user-friendly solution.

Lastly, the installation of water saving devices should be compulsory in every development of the International Zone.

H. Conclusions

The activities of the International Zone as defined today indicate the coming of public facilities as the main trend of development: national pavilions (maybe in clusters), students and researchers facilities, faculties, conference and exposition spaces, restaurants and visitors’ conveniences.

Accordingly the sanitation facilities will be localized in an area accessible to multiple users. This will simplify the maintenance, the related infrastructure and potentially the management of the generated waste matter.

A rather large part of the area will be green, due to relatively low building density in this zone. Whatever volume of pollutants is potentially harmful in such a close context, by increasing the polluted volume (water as a carrier) the risk increases proportionally.

Ecologically, the zone shows various fragile areas, like the canyon and water ways, and the groundwater connected area.

In this particular context, the soundness of eco-sanitation is obvious.

The process of implementing Eco-Sanitation should be done step by step: begin on a small scale and see how viable it is. According to the results, further development strategies or integration concepts can be undertaken.

Wastewater Management

A. Introduction

The goal of this chapter is to find the most efficient ways to treat wastewater in accordance with the ecological sanitation goals set forth earlier in the sanitation section of the proposal and the type of development that is expected in the International Zone as well as helping reduce pressure on groundwater.

The development of the International Zone is likely to occur slowly, rather than all at once, which can pose an interesting dilemma for planners of wastewater management. An effective system has to be scaled correctly and able to address future growth.

Considering the type of climate and availability of water in the region, and the diffuse and delayed nature of the planning, a decentralized system of wastewater management may be the most effective way of addressing the problem for this zone of Auroville. Natural decentralized systems offer on-site remediation of wastewater, vastly reducing the amount of water needed for transport of waste and the infrastructure that is required as well. There are also several other benefits to these systems including: low energy requirements, low maintenance costs, low construction costs and possible energy production from biogas and fertilizer. Decentralized systems also offer specific scalability to the site that is being built.

The International Zone is an area that in which we expect to have a large amount of users roughly 10 thousand per day, which has the capability of producing a significant amount of waste. This waste, however, will likely be dispersed between the major pavilion groups and can be dealt with on a case-by-case basis. An important consideration is the position of the International Zone, which lies on a hill that drains into an irrigation reservoir (the Irumbai Tank) and nearby agriculture area.

We must carefully consider the quality of water which is reintroduced into the environment after treatment. The decentralized systems of management allow for flexibility in the design of the International Zone by creating systems which address current waste flow levels, but can be easily expanded to meet the needs of future development without negatively effecting the environment.

B. Current Situation

Currently the International Zone (IZ) is very low in density and sees a moderate amount of visitors on a daily basis via the Visitors Center and the Matrimandir. The other structures currently in place are the Bharat Nivas complex, the American Pavilion, the Tibetan Pavilion, Savitri Bhavan, and the Unity Pavilion, plus a few communities. These structures may be considered examples of the other types of buildings that will populate the IZ. The places show a rather large range of wastewater treatment possibility, from basic combination of settler and soak pit to baffled reactor, vertical flow planted filter and even a segregation of grey and black-water with dry composting toilets! Although limited right now, the water throughput this area will increase significantly as development continues. The village of Kottakarai also lies on the edge of the International Zone, near the Industrial Zone. This village currently is poorly equipped with wastewater facilities and most of the inhabitants are night soil producers. There is much room and need for improvement in the village as the actual situation is a major risk for public health and environmental impact. Should appropriate measure of treatment be taken, it would significantly help the public health of the village, improve the water quality in the nearby tank and reduce hazardous risk to the groundwater.

C. Biological Principles of Sewage Treatment

Treatment of water rich in organic matter consists effectively of oxidization of organic material until it is stabilized. The process transforms the organic matter into substances of simple molecular structure and low energy content, which stay in the water unless they are transformed into compounds of higher structure due to other biological activities. However, the oxidation of organic matter does not occur (except at a much reduced level) by their contact with oxygen. It is necessary to have catalysts, that is, enzymes that realize this reaction. The presence of a great number of bacteria in wastewater provides the catalysts, such as respiratory enzymes, necessary for the reaction,.

Wastewater treatment processes are achieved using facilities that are designed to utilize natural, physical methods combined with the biological activity of microorganisms. Microbes used in the treatment facility are from microbial populations that occur naturally in the wastewater itself.

D. Why go for Decentralized Wastewater Management?

- More cost-effective than central sewer alternatives, except in densely populated, urban centers.
- Longer service life for managed on-site systems vs. unmanaged systems.
- Faster response to problems; smaller problem impact.
- Increased opportunity for better watershed management.
- Better ground water protection and management capabilities.

The proposed IZ will include many more buildings, most likely grouped in clusters, and surrounded by large amounts of open space for landscaping. This style of development makes a perfect setting for the use of decentralized systems because of their required space and on-site reuse of water.

Most of these systems can often be easily integrated into the natural environment or built into the complex. They then offer a significant amount of irrigation quality water for the surrounding landscape.

Natural, decentralized, wastewater treatment systems have the primary characteristics of being able to treat wastewater with less energy, less water use, and less maintenance. The systems mentioned here do not require chemicals or high amounts of energy. Some of the types of treatment are not ideal for the situation that Auroville is in, but have been addressed so that a clear idea of what is ideal can be reached. System capacities range from 1 to 1,000 cu. meters/day, which creates excellent possibilities for application. They provide effluent water that can be reused for irrigation as well as for certain household purposes if the designers choose. Physically, they can take up a considerable amount of space, but at the same time, can be easily incorporated in the surroundings. These systems can be designed to achieve any level of discharge standard, depending on the amount of time, space, and money invested in the system and the application of the recycled water.

Choosing and designing a decentralized system will depend on the amount of inflow, type of inflow, quality of effluent desired, and the amount of space available for the physical structure.

In the context of the International Zone, site evaluation should include:

- Vertical distance to seasonal high water table, bedrock, or other restrictive layer.
- Soil characteristics versus related infiltration area size requirements for approved treatment and distribution technology.
- Site slope, cover, terrain position, and hydrogeology.
- Horizontal distances and direction of surface water bodies or groundwater wells and their present and designated quality requirements.
- Horizontal distances to other physical features, particularly those in likely plume path.
- Site location and geometric orientation possibilities.

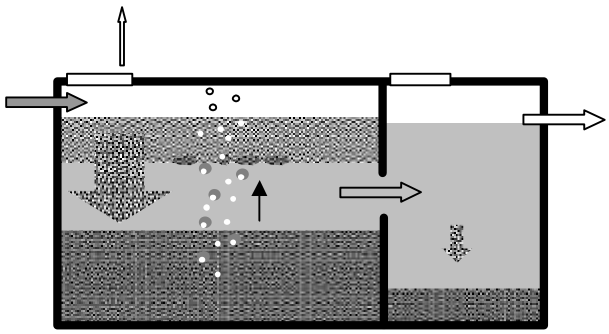
E. Proposed Development of Decentralized Systems

The following examples are different types of systems that can be used within the IZ to help meet the goals of sustainability. The main components of the wastewater systems are divided into primary, secondary, and tertiary types of treatment, each with a specific duty in the process of treatment.

1. Primary treatment

First level of treatment that removes the majority of settling and floating solids

Septic tanks – Standard underground sedimentation tank used to remove major solids out of the waste stream. They provide stabilization of sludge by anaerobic digestion of wastes - very simple to construct and very durable. They do need desludging on a regular basis according to usage to prevent clogging the rest of the system. It is best to continue with other underground forms of treatment after the septic tank to prevent odor and pollution.



Imhoff tank – Slightly modified septic tank that prevents the re-mixing of solids with liquids resulting in a cleaner, odorless effluent at a slightly higher cost and complexity of construction. This is ideal for places where above ground treatment (i.e. ponds) will be used to treat the water. Also requires desludging.

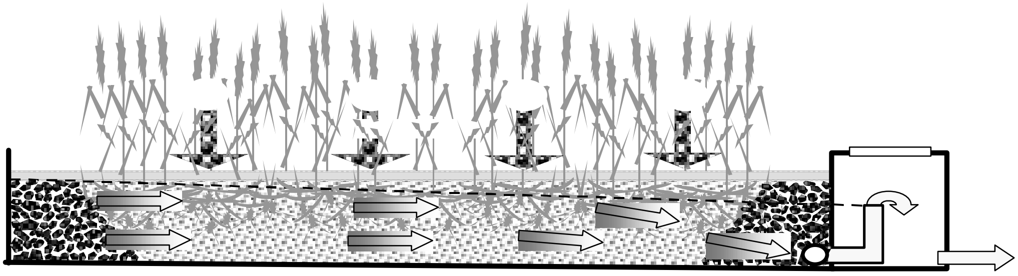
Settler – A settling tank is basically a crude septic tank designed to allow higher rate of flow through at the cost of some quality. These are common in high flow systems which are likely to get clogged. Because of this, settlers need be de-slugged on a regular basis.

Anaerobic pond – Sometimes used as a first treatment for industrial wastewater, anaerobic ponds are very effective for removing large amounts of biodegradable waste, so long as the system is not overloaded. They are fairly deep and require less surface area than other pond systems.

2. Secondary Treatment

Secondary treatment is used after primary treatment to dissolve the leftover organic matter in the waste stream.

Horizontal gravel filter (constructed wetland) – These run the water through an area containing gravel and plants that can effectively remove the harmful agents and pathogens in wastewater, even heavy metals.

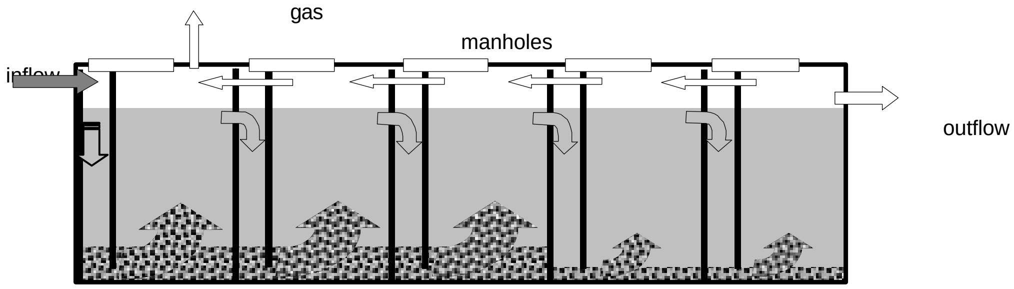


They can take up a considerable amount of space, but because they are mostly made of plants, they are not too much of an eyesore.

Filter material can be expensive depending on how it is acquired, and it can be more difficult to construct than other means of treatment.

Vertical Filter – A type of constructed wetland, the vertical filter uses several filter beds that are used to keep wastewater below ground as it is treated. Stabilized waste is a result of aerobic function. It requires half of the area of the horizontal filter and provides a better effluent quality, but at the expense of more necessary human input.

Baffled septic tank (baffled reactor) - Underground, wastewater is pushed through a series of specially designed tanks to allow anaerobic degradation of waste. This is a fairly large part of the system, but size will depend on the quality of inflow.



Inoculation of fresh wastewater with active sludge

The reactor forces water through sludge and then up over a baffle, allowing more and more solids to settle out with each consecutive section.

Anaerobic filter – Small in size, also underground, this forces water through a filler material on which anaerobic bacteria can break down non-settling solids and other dissolved organic matter. This can be costly depending on the type of filler material used. This is often used in conjunction with a baffled septic tank to achieve a higher level of cleansing

***UASB – Upstream Anaerobic Sludge Blanket Reactor*.** This type of system is found often in decentralized management applications but is questionable for Auroville because of the high amount of energy required. It is useful in situations where waste inflow levels will be fairly constant or can be regulated. These can be a very effective solution, but require more attendance than other systems. The system also takes several months to mature and achieve desired cleansing levels. Biogas is emitted and can quite easily be captured.

Lagooning system – Ponds that are either anaerobic or aerobic in nature, can be used to stabilize wastewater with very little maintenance and attention. They do require an area where a pond will not intrude on the landscape. For anaerobic ponds and aerobic cum facultative ponds, mosquito breeding and odor can be a nuisance, so they must be kept farther from working areas. Successful lagoon systems usually include several ponds for different purposes, one for sedimentation, one for aerobic and facultative digestion and one for polishing (which is addressed later).

Horizontal filter – This system is fairly large, but requires little to no maintenance and is very simple. It can also be designed to look very natural with the surrounding environment. This system sends wastewater through a planted bed, and is always soaked. It stabilizes waste through the aerobic and anaerobic digestion of matter.

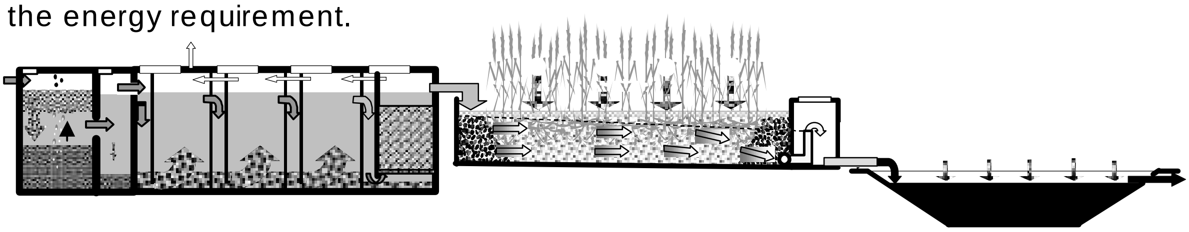
3. Tertiary Treatment

This is the final stage of treatment, and is very important for the safe reuse of water. This level of treatment is primarily for the removal of pathogens and other unsafe contaminants not removed by earlier systems.

Anaerobic pond – Anaerobic ponds can also be used for tertiary treatment.

Polishing pond – A type of aerobic pond, they depend on oxygen for the destruction of wastes. Usually the final step in most waste treatment systems, it has a high rate of pathogen removal and can be used as a fish pond which, in turn, cleans the water even further.

U.V. treatment – One of the most effective ways, but not always necessary, of removing harmful pathogens is to subject the wastewater to high amounts of U.V. radiation, either by shallow ponds indirect sunlight (which increases water loss to evapo-transpiration) or by artificial subjection to U.V. rays which can require a lot of energy. Artificial U.V. treatment is not recommended for use in Auroville because of the energy requirement.



It must be mentioned that the devices in the secondary treatment phase are also acting, sometimes to a large extent, on pathogen control. It is even possible in some cases to reach discharge level from them.

4. Other parameters

The systems described above are not the only ones that can be considered as decentralized systems. But on top of decentralization, we consider that other parameters must be covered in the proposed systems to be sustainable:

- natural process (no chemical input required)
- power requirement only if gravity flow is not possible
- ease of operation
- low maintenance

These systems can be combined in various ways to achieve the required level of purification in an optimum manner.

5. Efficiency

The previous methods of waste management have been proven to work in many circumstances in India. About 50 examples of decentralized wastewater treatment system have been developed by Auroville in the city as well as elsewhere, ranging from as few as 2 people all the way up to 1600 users. While the main target is domestic wastewater, various cases of industrial effluent have also been taken care of.

The following table gives an idea of the surface versus efficiency for various decentralized systems. Other factors may play a major role in choosing and designing wastewater treatment system (soil bearing capacity, water conservation...). Combining various systems is perhaps the way to get the maximum result with the minimum space requirement.

[31]	Surface required m2/m3	Efficiency in BOD5 removal %
Septic tank	0.5	25 to 35
Imhoff tank	0.5	25 to 35
Anaerobic filter	1	70 to 90
Baffled Reactor	1	70 to 90
Constructed wetland	30	70 to 95
Horizontal planted filter	2 to 3	70 to 95
Vertical planted filter	1	70 to 95
Anaerobic pond	4	70 to 95
Facultative aerobic pond	25	70 to 95
Sludge drying bed	0.1 to 10	

F. Re-use of Waste

One of the greatest benefits of decentralization is the ability to re-use water and solid waste in the same place that it originates, creating a circular pattern of flow and reducing new water input.

[31] BORDA – Decentralized Wastewater Treatment System

Once the water has undergone a natural treatment process, it is not generally considered hygienically safe, but is often used for flower gardens, fish ponds, landscape watering, and flushing toilets. Applications for this treated water are limitless, so long as it is not used for cooking, bodily cleaning or other situations where hygienic water is normally used.

The level of purification in the water is a direct result of the type and extent of the system. Should sanitary water be required, it is possible with the addition of more energy, technical facilities and money.

DISCHARGE REGULATION OF WASTE WATER PER LAW IN INDIA					
		discharge into			
Parameter	unit	inland surface water	public sewers	land for irrigation	marine coastal area
SS	mg/l	**100**	**600**	**200**	**100**
pH		5,5, to 9	5,5, to 9	5,5, to 9	5,5, to 9
temperature	°C	max. 5°C above			max. 5°C above
BOD5	mg/l	**30**	**350**	**100**	**100**
COD	mg/l	**250**			**250**
oil and grease	mg/l	**10**	**20**	**10**	**20**
total res. chlorine	mg/l	1			21
NH_3-N	mg/l	**50**	**50**		**50**
N_{kjel} as NH_3	mg/l	100			100
free ammonia as NH_3	mg/l	5			5
Nitrate N	mg/l	10			20
diss. phosphates as P	mg/l	5			
sulphides as S	mg/l	2			5

G. Separation of Waste

The separation of waste, as addressed in the sanitation section, is another way of dealing with waste on a decentralized level. It also allows for the reuse of wastes, but only after thy have been composted. Urine, uncontaminated by feces, is a relatively sterile and safe substance. If urine can be collected and stored, it can be used as a very effective fertilizer, being full of the nutrients that our bodies are unable to use. Feces on the other hand, must be handled carefully. If minimal water contact is maintained, such as the case in dry toilets, it can be stored with relatively low levels of odor.

The advantage of having drier solid waste is that dry composting is much more effective for removing pathogens and should be used whenever possible. The stabilized sludge that is taken from the bottom of septic tanks, baffled reactors and ponds can also be composted with the addition of some other organic matter. Effective microorganisms (also known as EM) can also be used in order to speed the composting of the waste and generate a highly valuable product. After the composting of the waste, the soil can be used safely as a fertilizer.

H. Biogas

Biogas production is a by-product of the anaerobic degradation of waste. It is really only useful on larger scale systems, where a significant amount of gas will be produced, or where the wastewater is producing a natural, high organic content. Should there be a useful application for the gas that is produced, there are several types of gas harvesting systems that can be used, including integrated ones, according to the type of system they will be harvesting from.

I. Effective Microorganisms

Microorganisms naturally occurring in the waste may not necessarily be the most effective and efficient microbial communities to act on the wastewater in the collection and treatment process in order to achieve the desired effects.

It is observed that the introduction and maintenance of specific microbial cultures as a method of operating the treatment process increase the efficiency and effectiveness of existing or newly developed treatment facilities. For new systems, the impact on sizing and therefore cost is far from being negligible

That is the basis on which EM technology may be introduced in wastewater treatment facilities.

J. Conclusions

The standard practices of water use in and around Auroville have left the water resources in a fragile state, and with the growth of Auroville, it is absolutely imperative to address the issue of water scarcity. Using a natural, decentralized wastewater system is a very effective way for Auroville to address the problems of water consumption and give a positive example to neighbors of the surrounding bioregion. Safety can be maintained while water conservation is pursued.

Decentralized systems are very effective so long as they are maintained properly, and the effluent that is released is relatively free of pathogens, but unless further steps of cleansing are used, the water typically should not be used for drinking or other hygienic applications. The water is best suited for irrigation purposes and non-hygienic cleaning.

Indeed, such systems are flexible and allow for the continued development of the area as planned. Use of natural, decentralized systems offers a significant savings of resources, in both time and money, to the developers in the International Zone. If integrated at zone scale level, it simply suppresses the need for large sewers, with all the design, planning, infrastructure development and cost.

By combining decentralized wastewater management with water saving techniques and recycling on site, the cost reduction together with the environmental impact is simply remarkable.

This document should provide the necessary information for making a decision about what kind of treatment system to use in the case of the International Zone. If further information should be required, such as assistance in designing a specific system to meet particular needs, technical capacity and guidance is fully available from Auroville itself.

Water Distribution

Looking at the actual level of planning and clarity of the definition of the activities which will come in the International Zone, we do not think it makes much sense to develop a detailed evaluation of the water distribution in the area.

We will only define the main lines of thinking in accordance with the general concept proposed so far.

A centralized water system seems very unpractical at present since it is very expensive, difficult to develop in a scalable way and not sustainable in such a context. More over, the viability of the various possible components has to be assessed before being developed on a larger scale. That is the only reliable way environmentally sound development can be done. It is then suggested to go for interconnected, de-centralized systems, which will fit with local needs and offer maximum freedom for further development.

Water distribution systems must be flexible enough to allow modular development according to the growth of needs and population. The general networking should be on a closed loop, to allow ease of pressure equalization and maintenance.

Interconnection from one local system to the next creates room for development at any stage and according to the needs.

A five year plan base seems to be a correct way to define and size the network.

A relatively minor investment would be needed for the network as such, and the major infrastructure (Underground tank, Overhead tank...) can be developed step by step. It must be noted that an overhead tank, one of the major investments of any distribution system, can be drastically reduced if the planning of the concerned area is clear enough.

Where 1 to 3 days of consumption is required for sizing an underground storage capacity for a smooth water supply (depending on the number of reliable water sources), an overhead tank can be limited to a volume corresponding to 2 peaks hours of consumption. The option of a pressurized tank must be investigated too.

Integration of the villages

"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. This of course begs the question, who are all its citizens?"[32]

A. INTRODUCTION

A little girl playing in Kottakarai

The villages are an already existing part of the Auroville landscape, just as the villagers are a vital part of the workforce of Auroville. In any landscaping or development plans the villages must be integrated. This is particularly necessary for water management as Auroville shares water resources with the surrounding villages.

For the International Zone this means that the existence of the village of Kottakarai, located in the SW part of the IZ, cannot be ignored.

In formulating plans we must work with the ground reality.

[32] Creating a Sustainable London. Sustainable London Trust, 2000

The most crucial part of the International Zone as far as the quality of water is concerned is Kottakarai.

Kottakarai is estimated to have the highest permeability rates in the zone, particularly in the canyons where many people defecate and throw their garbage. There is a real possibility of pollution going directly into the aquifer because of high infiltration. Sanitation facilities and further solid waste management is crucial for the water quality of the entire zone as well as to prevent disease. Sustainable water management is not possible without the integration of the villages.

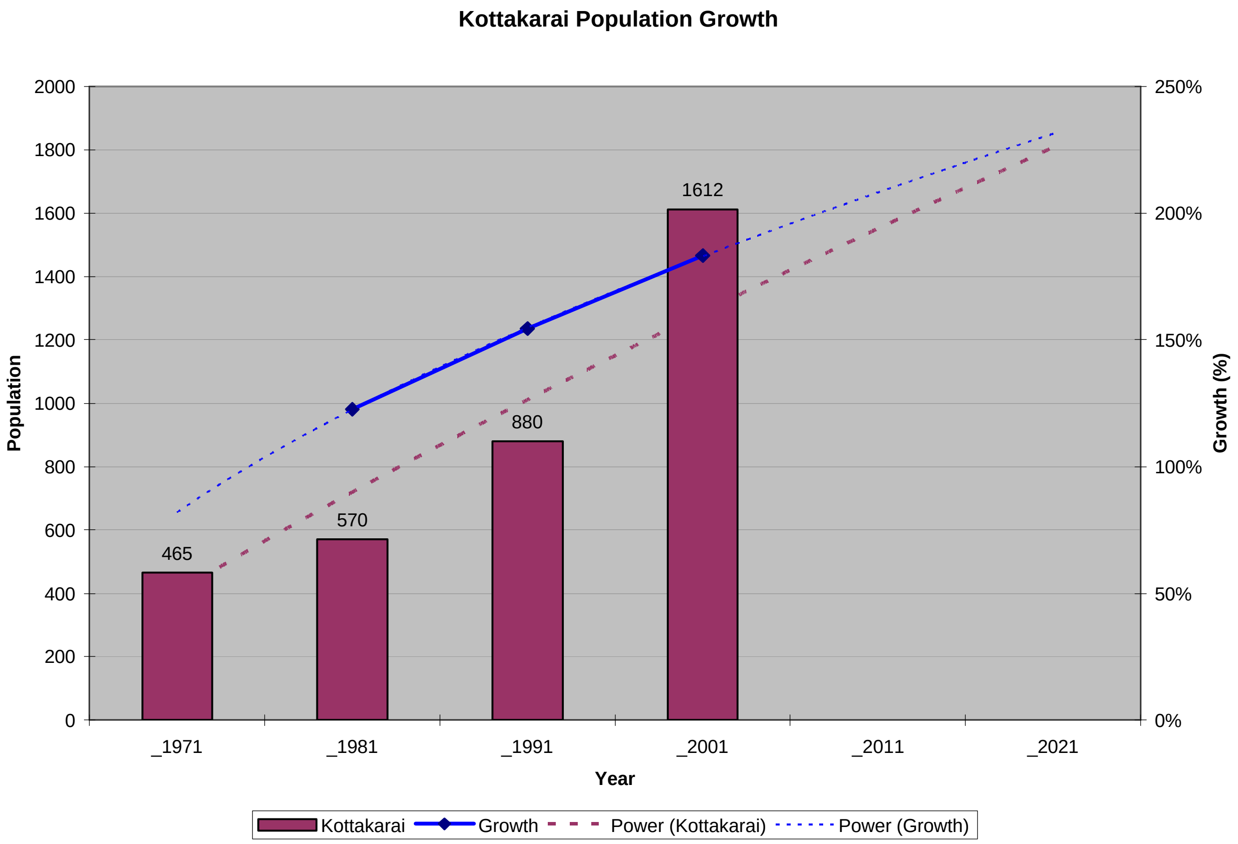
The main surface water issue there is the quality of the Irumbai tank and the network of channels that flow into it. The Irumbai tank recharges the ground water and is used by some surrounding rice paddy farmers directly for irrigation. It is important to remember that it is upstream from the Kaluvelly swamp, so pollution going into the Irumbai may affect many of the other tanks and channels in the Kaluvelly drainage network, and eventually the swamp itself.

Garbage near the canyons in Kottakarai

In Kottakarai, the problem is the pollution going into the channels. Pollution in the form of garbage, human and animal waste, and other unknown contaminants go directly onto what is defined as highly permeable surfaces. This may directly pollutes the Irumbai tank, and has a high probability of affecting the aquifers, very close to the surface most of the time.

There have been limited geological studies done on the infiltration in the canyons and surrounding area. However, based on the information we do have it appears that the canyons have very high infiltration rates, the highest in the International Zone. More geological studies must be done to get an exact picture of the infiltration rates. The high infiltration rates could mean that pollution is going quickly into the water table, possibly too fast to adequately filter it out. This factor, combined with high extraction rates, mean people may be extracting this polluted water for drinking purposes rather directly. This also means a high risk of disease.

By looking at the population growth curve, we come to the natural conclusion that the existing problems can only worsen in the coming years if not taken very seriously right now.



B. A strategy

Achievement of sustainable development requires attention to the securing of sustainable livelihoods and poverty reduction. Promotion of sustainable livelihoods has to be based on a holistic framework which takes into account the total environment in which individuals, households and communities operate. This includes the natural environment (natural resources), the built environment (infrastructure and services), the economic and political environment and the socio-cultural environment (regulatory mechanisms, rights frameworks, etc.) which influence the management and distribution of resources and services.

Issues of rights, access and control over resources are crucial to sustainable development and poverty reduction strategies.

The successful improvement of water supplies and sanitation requires an understanding of the interconnectedness of water and sanitation. It is understood that inadequate improvements to sanitation can be worse than no improvements at all, particularly in the case of sanitation approaches which use scarce freshwater resources and risk contaminating water sources.

In the fast changing context of Auroville's villages, one can observe that the male population is working outside more and more, and therefore not directly involved in the daily preservation of the village's life, and more particularly water related issues.

It is important to bring gender perspectives into the development of strategies to promote sustainable livelihoods. Such strategies cannot succeed if they leave out the perceptions, knowledge, contributions, needs and priorities of 50 percent of the population, i.e. women and girls. [33]

C. Solid Waste Issues

In order to cut down on pollution, sanitation and proper solid waste management is necessary. Recently, Harvest staff conducted a village survey on sanitation and solid waste practices. It is from this that most of the following information has been gathered. Currently there is a solid waste management program in Kottakarai. **Eco-san** in Auroville picks up recyclables and garbage from the villagers and pays them a small amount for it. However, this is not done everywhere in the village and could be expanded. Particularly, this is not done in any part of the Dalit (untouchable) colony and only sporadically done in Barathipuram, located in the Southern part of Kottakarai close to Auroville. These two areas are also areas where much of the garbage is put directly into the canyons. Why these activities are not happening in these two areas must be further investigated.

Many Auroville farms purchase compost and cow dung from villagers and quite a few people use their own compost on their own lands or gardens.

[33] Carolyn Hannan Ingvar Andersson

Garbage in Barathipuram

However, again composting is not practiced in the Dalit colony. The reason given for this was a lack of cooperation between the villagers to come together and create a compost pile. Also, Auroville communities using biogas often buy the necessary cow dung from the villagers.

All of these programs are turning waste into a resource, and creating mutually beneficial relationships between Aurovilians and the villagers. There is potential to expand these programs specifically into the dalit colony as this was a desire of many villagers that we talked to. Training on composting may be very helpful for the villagers in the colony.

D. Sanitation

The Public Toilet in the Dalit Colony

Proper sanitation facilities are also needed to decrease pollution, as well as disease. Through our case study we discovered that most people in the villages do not have their own bathrooms and there are currently only two public bathrooms in Kottakarai, only one of which is completely functional. More sanitation facilities are necessary to meet the basic needs of the people.

The functional public toilet is in the dalit colony. It is very successful with many people using it. It could be used as an example for other public toilets. It was built about eight years ago by the Auroville Health Center.

The facility includes two women's and two men's toilets and a bathing area for each. There is a government water tank next to the facility. The toilets are the traditional water-using Bombay style toilets.

The facility is kept up by a woman guard, named Manamma, who does all of the cleaning and maintenance and is paid by the Auroville health center 900 rupees a month (100Rs going directly into a savings program). This is not a lot and she would like more. She is the only employee.

Mannama in front of the Washing Facilities

The Clean Bombay Style Toilets

This public toilet is helpful; however, it is not enough. There are estimated to be over 100 people in the colony and only this one facility.

Many of the villagers said that they needed another facility, preferably on the other side of the colony closer to the main road. I think we can use the framework of this public toilet as the basis for building other ones.

As water is scarce in the villages, it was important to all the people we talked to that a water tap be included along with any bathroom facilities. Most people use public taps from which water only comes out once or twice a day for a half hour. Many people said they only get 3-4 pots of water a day for their entire family. Water is their first concern. Therefore it seems necessary and makes sense that any public toilets include a public tap or water tank for drinking water.

The Gov. Public Toilet in Barathipuram

The other toilet is in Barathipuram. It was built by the government just 8 months ago. It is not used often for bathroom purposes due to water scarcity and lack of cleanliness. However, it is used for washing clothes and as a water tap for drinking water. Its lack of cleanliness was voiced as one of the major reason for the lack of use. It is only cleaned every couple of days and some people said the government is not supplying buckets for the toilets. Water is also very scarce in Barathipuram. There seems to be a lot of fighting going on around this and more taps were desired by almost everyone we talked to. More research needs to be done to see if the government is planning on improving this situation, though it seems doubtful. In the dalit colony there is a row of houses built by the government on Ambetarnagar St. Some of these have bathrooms; however, they are structurally unsound causing flooding and cracking throughout the house. Because of this they cannot be used. There didn't seem to be any plans to fix them. So if this is any indication as to how the government deals with these situations, it doesn't look very optimistic.

As for solutions, it would be ideal to work with the government to improve these facilities; however, this may be problematic.

E. Dry Toilets Possibilities

Other types of toilets should also be explored. Since water is so scarce its use should be kept to a minimum, if any. One suggestion is to have a case study to implement domestic dry toilets or at least public dry toilets. However, this would be challenging because culturally the handling of feces and urine is very problematic. One case study in The Rajendra Nagar slum proved to be successful in overcoming these problems. The toilet center in Rajendra Nagar separated urine and feces, using the feces for compost. It now has 800 users a day.

According to the study assessment, “Considerable time and effort was made to convince the people that human feces were not a waste product, but a rich resource for production of compost. – To this date, the toilet system is working satisfactorily and to our expectations.” They worked on four aspects: cultural and social, technical, economical, and safety. They are looking into further methods to increase technical efficiency and upscale it. They found it economically feasible, but did not reach the target of covering all costs by the generated income. They are working on curtailing expenditures. The women were particularly happy with the toilets as they were kept very clean and security wardens kept it safe. A case study of this kind appears to be a feasible first step in implementing sanitation into the villages.

F. Traditional Water Drainage System

A long-term plan for the Irumbai tank includes bringing back the traditional rain water drainage system. This system utilized a network of eryes and channels to irrigate the fields. It needed regular maintenance and awareness of water levels. The British did not like the fact that it was labour intensive and abandoned it. After a while the system deteriorated due to lack of maintenance. Re-utilization of this system would be challenging, but very beneficial, especially as the disadvantages of groundwater extraction increase. Re-utilization of this traditional system should be looked at as a long-term process/goal and more energy and research must be put into it.

G. Conclusions

The villages need very much to improve sanitation, solid waste management, water quality, and water availability. There are currently some positive solutions offered as a response to these issues, including the existing successful public toilet in the colony and the eco-san programs. Expanding these existing successful endeavors could greatly help the villagers and their water quality as well as strengthen the relationship between Auroville and Kottakarai.

This is also what the villagers themselves desire. It will be important that the villagers have a strong say in all stages of development. This is not only respectful, as it is their home, but it is also necessary for successful implementation of the programs or toilets. Dry toilets could be explored further, especially with the existing water availability problems; however, this must be done sensitively, as it is culturally problematic. Also other types of low-water use toilets should be explored.

Expanding the Eco-san and composting programs could create more positive networks between Auroville and Kottakarai on many different levels. Some problem-solving skills may be necessary to overcome the reasons for not composting or selling their garbage to Auroville, specifically in the colony and in Barathipuram. As for composting, workshops on how to compost could be helpful. Then, hopefully, more farmers could buy compost from villagers. If more biogas was used in Auroville, villagers would have access to more cow dung, helping to eliminate that waste from the streets and the groundwater.

In conclusion the area of Kottakarai is one the most crucial parts of the International Zone, as it contains the central drainage channels and the only water tank, the Irumbai, in the zone. It is vitally important to address the waste going into these aquifer recharge areas. The further deterioration of these areas would mean the deterioration of water quality for the entire zone. Planning for this zone must address this issue now before it becomes a huge problem. Lastly, we must always remember that Auroville is not an island and in order to manifest its vision, development plans cannot be created in a vacuum.

General Conclusions

At the end of this multi-angled reflection, we can conclude that a few immediate steps are required pertaining to various fields.

1. Geology and soil permeability need further investigation, to consolidate the understanding of the potential impact of the development of the International Zone, as well as the appropriate sizing and location of the main components of the stormwater control and landscaping devices.

   It is proposed to develop systematic grids of sampling on these two parameters, then to complete the geological map and soil capacity of the zone.

2. The village of Kottakarai is a major and most problematic topic to the consolidation of an integrated water management system for the International Zone.

   It is proposed to develop a full sanitation concept, including social mobilization and awareness campaigns, construction of facilities and maintenance, for the village and its extension.

3. Integrated water management for the International Zone depends highly on better storm water management and landscaping techniques, which then may affect greatly the general layout of the zone.

   It is proposed to develop an implantation map of the main physical features of the Zone as per the above-mentioned parameters. It should help the planners and architects to develop a sustainable area.

Further, the designers, architects and constructors must systematically integrate the following points:

Water saving devices. While not demanding most of the time any extra expense, the positive impact on the environment, as well as the amount saved on infrastructure, cannot be underestimated

Rainwater Harvesting. While being compulsory now in Tamil Nadu, we can only highly recommend integrating such techniques in the buildings and the surrounding landscape.

Wastewater management & on site sanitation. The trend of development of the International Zone as well the demand of sustainability advocate on site treatment and recycling. This will be of tremendous effect on the infrastructure cost, but also will create a positive resource out of waste.

Appropriate plant species and landscaping: Consistency on this subject will create beautification together with microclimate control and a low input-demanding environment.

We cannot underline too strongly the need for a coherent approach to mobility and road classification, as a major environmental impact factor.

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." [34]

[34] Brundland Report, *„Our Common Future"*

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