RAINWATER HARVESTING, ALTERNATIVE TO THE WATER SUPPLY IN INDIAN URBAN AREAS: THE CASE OF AHMEDABAD IN GUJARAT

(Akil AMIRALY[1], Nathalie PRIME[2], Joginder P. SINGH[3])

ABSTRACT

Water scarcity is a characteristic of north-western states of India, such as Gujarat. Over time, the continuous increase of the population as well as the financial, administrative and technical deficiencies of the new supply system have lead to the deterioration of the water service in the city. In the meantime, the water demand has considerably increased due to the improvement of standards of living. This has resulted in an increasing pressure on underground water resources, which has lead to an alarming depletion of aquifers. From this overall situation arises the question of the use of complementary alternative sources of water in Ahmedabad and more particularly of the rehabilitation of the rainwater harvesting structures still existing in its old city area.

The objective of the research is to evaluate to what extent this traditional system may constitute an additional source of water within the Old city of Ahmedabad and may locally reduce the pressure on water demand, assuming that the existing supply system does not fulfil the needs of the users. The results of an exploratory field study conducted in the Old city in 2001-02, which combined quantitative and qualitative aspects, give an outlook on people's opinions and behaviors regarding both systems. Finally, the rehabilitation of rainwater harvesting structures in the Old city of Ahmedabad suggests the necessity of empowering local structures of water management (households, non governmental association) in semi-arid urban areas to create the conditions for a sustainable implementation.

---

[1] Ph. D student, Centre de Recherche en Gestion (CRG), Ecole Polytechnique, Paris, France.
[2] Associate Professor of International Management at the European School of Management (ESCP-EAP) in Paris, France.

INTRODUCTION

Water scarcity is a characteristic of north-western states of India, such as Gujarat. In that context, people have developed, over the time, techniques to meet their water requirements. Rainwater harvesting is one of them. It was functioning in the Old city of Ahmedabad before the extension of the modern water supply system to the entire town till the middle of the 20th century. The continuous increase of the population in the following decades as well as the financial, administrative and technical deficiencies of the new supply system have lead to the deterioration of the water service in the city. In the meantime, the water demand has considerably increased due to the improvement of standards of living. This has resulted in an increasing pressure on underground water resources, which has lead to an alarming depletion of aquifers. The growing water demand in both rural and urban areas has prompted the successive governments of Gujarat to bring water from far away which is economically, socially and environmentally unsustainable on the long run. From this overall situation arises the question of the use of alternative sources of water in Ahmedabad and more particularly of the rehabilitation of the rainwater harvesting structures still existing in its old city area.

1. OBJECTIVES AND FOCUS OF THE RESEARCH

The issue raised here relates to the search for complementarities between the present system of water supply and the alternative system of rainwater harvesting, in a context of water scarcity. The objective of the research is to evaluate to what extent this traditional system may constitute an additional source of water within the Old city and may locally reduce the pressure on water demand, assuming that the existing supply system does not fulfil the needs of the users.

---

[3] Professor of International Management at the Indian Institute of Management Ahmedabad (IIMA), India.

From that perspective, the results of an exploratory field study was conducted in the Old city in 2001-02, which combined quantitative and qualitative aspects, that gives an outlook on people's opinions and behaviors regarding both systems. Finally, the rehabilitation of rainwater harvesting structures in the Old city of Ahmedabad suggests the necessity of empowering local structures of water management (households, non governmental association) in semi-arid urban areas to create the conditions for a sustainable implementation.

2. LITERATURE REVIEW

2.1 The Development and the Decline of Traditional Water Management Systems

The monsoon season. "In Indian literature, it is literally depicted as the season of love – a time when Mother Nature renews herself and gives everybody a precious new lease of life, and young girls hang swings on tree boughs and sing love songs. Once the rains disappear, the land becomes as dry as a desert, life is difficult and water scarce to find. The gushing streams which overflow their banks in the monsoon months soon become tame or dead" (Agarwal and Narain, 1997, p.25).

2.1.1 The general context: water and people

If Indian literature casts so much light on the monsoon, it is because this climatic phenomena is at the heart of people's life in the Indian subcontinent. Since the Indus Valley civilisation (2500-1500 before Christ) that gave birth to the first urban centres, Man has appropriated this source of water. The reason is simple: most of the rainfalls occur within few days or within some hours of heavy rains. Therefore, over the years Man has developed indigenous techniques to collect and store water during the dry season until the following monsoon.

Due to the diversity of climates, the concept of water harvesting is materialized by a variety of techniques over the territory, in relation with physical situations, existing materials and people's needs. The inhabitants and more extensively the rural or urban communities they belong to are the nerve centre of the functioning of local infrastructures. These people are both the initiators and the managers but also the warrantors of these systems.

Due to the colonization and the subsequent introduction of new technologies, most of these traditional systems had been broken down during the last century. Along with their liquidation, most of the knowledge on these techniques has also disappeared: their use has declined as also the confidence of the people in these systems. Nowadays, the deficiencies of the water management by Public authorities and the economic, social and environmental costs of large infrastructure projects pushes the civil society, under the impulsion of the NGOs into claiming the valorization of these techniques and their re-appropriation. Moreover, the successive droughts in arid and semi arid areas in north-west India results in a growing number of rural communities to go for alternative solutions such as rainwater harvesting in underground cisterns or artificial ponds.

In such a context many authors have focused on the issue of alternative systems of water supply. Most of the sources of this literature has been written during the last decade and it highlights two phenomena: the growing dissatisfaction of the civil society concerning current water management systems and the increasing movements for the rehabilitation of alternative management systems. In the next section, we will analyse the growth and the decline of alternative water management systems, emphasizing the links between their development and the people's participation.

2.1.2 The development of traditional water management systems

The development and decline of these systems has not been very much explored, except by historians whose contribution should be appreciable, since sources on the subject are scarce.

Role of individuals in the development of these traditional systems

The major role of individuals, notably, philanthropists and communities in the construction and the maintenance of traditional water management systems is a permanent feature. Actually, there is a religious benefits associated to the infrastructure construction related to water. “To the orthodox Hindus, among different forms of charity, one of the most important was the provision of water” (Agarwal and Narain, 1997, p.281).

Reflection of the social stratification

The political power, represented by the monarch or the local chief financed or encouraged the large irrigation projects. Once constructed, the management and maintenance of these infrastructures depended on the populations. Nevertheless, “innumerable smaller works were constructed at the initiative of individuals and local communities” (Shankari and Shah, 1993, p.19).

The construction was probably in the hand of families specialized in the construction of such specific structures. Nowadays, some families are still perpetuating the know-how of the construction of underground rainwater harvesting cisterns, in the Chittoor district of Andhra Pradesh or in Diu in Gujarat. “There were caste communities specialised in earth and stone work called *wadders* and *boyis*. They undertook the construction of tanks, wells, roads and works where earth and stone was involved. Even today they are the main source of labour for Irrigation and Roads and Buildings Departments” (Shankari and Shah, *op.cit.*, p.27).

One deficiency remains : none of the sources give any information on the cost of construction and the repartition of the resources between the inhabitants.

Role of the family in the timelessness of the system

The information related to the management and maintenance practices are limited and incomplete. In the southern part of the country, the maintenance of supply channels and fields channels was shared out among the members of the communities using it. “Known as *kudi maramath* in the south, it was a widely prevalent practice all over India. Wherever, a repair work needed to be attended to, such as cleaning of the supply channel, each family was required to send an able bodied person to contribute labour for the work If it was not in a position to do so, it should send a hired substitute or contribute the money required for it" (Shankari and Shah, *op.cit.*, p.28).

Circulation of know-how

In water management, the technology transfers from the Middle East and Persia (in particular) to South Asia are historically acknowledged. "The technology of *qanat* was adopted by the people of the Malabar Coast to build *surangams* to meet their drinking water needs". Another example is the building of "the *qanat* based water supply system of the town of Burhanpur in Khandwa district of Madhya Pradesh"(Agarwal and Narain, 1997, p.29).

It is reasonably sure to assume that the concept of rainwater harvesting in underground cisterns was imported from regions situated in the Western part of the subcontinent. This system already existed in the 16th century in Herat, an Afghan city in the Khorasan region or even further west, in Constantinople (Minor Asia). Earlier, archaeological evidence of rainwater harvesting in over-ground tanks is available at Dhola Vira structure in Gujarat.

2.1.3 The decline of traditional water management systems

Resources repartition and prosperity

When the British arrived on the subcontinent in the 17th century, the patchwork of kingdoms that later gave birth to India was the richest region highly urbanised in that time. The development of towns and the opulence of Indian courts were based on the surplus of wealth generated in the villages that produced a large quantity of goods. The Indian courts encouraged the production and the mass export of luxury products such as textile and jewellery. An ingenious water management system was to some extent at the origin of the economic growth.

The short monsoon season required an equitable repartition of resources between the rural and urban areas. "There were hundreds thousands of tanks across the country. Locally developed technologies were further supported by an elaborate system of property rights and religious practices" (Agarwal and Narain, *op.cit.*, p.274).

Local strategies and sustainability

Leyes Ferrouki (1997) underlines that "even though these traditional rainwater harvesting systems can look precarious and casual in the eyes of modern technologists, they have been perfectly suitable for centuries. The reason for this is that they are compatible with local lifestyles, institutional patterns and social systems. They represent a fund of solid experience gained through generations of observations, trials and errors". This author adds: "the often forgotten relationship between regions of high biodiversity and high poverty is often very clear in India (…). This combination has allowed the development of numerous sustainable indigenous survival strategies. The diversity of rainwater harvesting techniques in the arid region of Kutch affected by the high water salinity illustrates this situation". Ferrouki regrets that "many of these techniques have disappeared or are disappearing along with their innovators, since the modern civilisation is forcing them to abandon their land and ways of living".

These know-how constitute a major cultural and technical heritage because, in a general context of scarcity (of water and financial resources), they highly contrast with programs involving high cost technologies and leading to questionable results. It is therefore relevant to identify the historical factors that have generated and accelerated the disinterest of Indians for their own water management system.

Destabilisation of the economy and of the social institutions

The Cipayes mutiny in 1857 has marked the ascendancy of the British Crown over the Indian subcontinent. "The British neglected systematically the resources they could not own or earn money from"(Agarwal and Narain, 1997, p.309). The production system formerly designed for the satisfaction of the local demand was turned around to produce goods for the metropolitan market of the colonizing power. The pattern of agriculture evolved from subsistence farming to cash crops for the colonial market.

These successive choices have destabilized the local political institutions which had previously managed local water infrastructures, such as the *panch* or local committee. Without sufficient incomes, the lands and renewable resources that belonged to the community could be used by anybody without any constraint: “What were once community managed commons turned into free access resources” (Agarwal and Narain, *op.cit.*, p.309). The traditional system of maintenance had collapsed. The newly bureaucratic and centralized system set up by the colonizers was not designed to maintain the innumerable water works scattered over a vast territory. The British’ taking over of the local administration was the beginning of the collapse of the village communities run by its inhabitants.

Centralisation of power and infrastructure deterioration

According to Shankari and Shah, the eagerness of the colonizers in exploiting the country’s resources and their misunderstanding of the traditional water management systems drew them to marginalize the existing infrastructures. “When the British government realized that repairs and restoration of hundreds and thousands of tanks would involve very great expenses, it tried to enforce *kudi maramath* by compulsion and by legislation” (Shankary and Shah, 1993, p.29). This initiative failed. In contrast, Ballabh and Choudhary (1999) notice that the colonizers initiated the construction of large infrastructure projects such as canals since this kind of infrastructure was much more adapted to cultivate large crops and increase State’s incomes.

Having been educated in English language during the Empire and known as *brown sahibs*, the Indian elites were behaving like their masters in terms of water management. Accultured in their early age, they reproduced the mindset of the administators they were succeeding to. After the Independance, the construction of large infrastructure projects was achieved by engineers sharing with their predecessors the same disdain for water systems managed by people. The decline of traditional structures of management was patent. If we refer to Shankari and Shah, it was the time when “tanks bed have become municipal garbage dumps, housing colonies, bus station” (Shankari and Shah, 1993, p.37).

These authors note that "the greater centralisation of policy has reduced village *panchayats* to the lowest administrative wings of the state governments with very limited powers and jurisdiction. Informal associations such as cast councils have also lost their legitimacy and authority, with modern courts and policy taking over their functions however ineffectively. New social bases of power have emerged replacing the old village leadership. The new leadership is oriented more towards competitive electoral politics rather than the old style politics of consensus. In the meantime, government has so expanded so much in the name of development that there is little space for people's initiatives. People have come to expect the government to carryout every developmental/welfare activity" (Shankary and Shah, 1993, p.37).

2.2 Water Scarcity in Gujarat

2.2.1 Main Characteristics of Water sSarcity

Water Availability: Rainfall Patterns and Physical Data

Water as a resource is available as groundwater and surface water. There are major regional variations in the availabilty of water in the state due to variations in physical factors such as climate, hydrology, geology, soils, topography and vegetation. (...). In Gujarat, the climate is semi-arid to arid, except in the southern part of the state where there is a wet sub-tropical climate. Rainfalls have a high intensity and a short duration; they are concentrated in the monsoon season (July to September).

Measuring water scarcity

There are different criteria to measure water scarcity. If we refer to the *White paper for water in Gujarat*, the most widely used criterion to measure the water is the level of annual renewable freshwater supply of water per capita (Falkenmark, XXXX). If it falls below:

- 1.700 m^3, there will be local shortages of water;
- 1.000 m^3, water supply begins to hamper health, economic growth and human well being;

- 500 m^3, water availability becomes a primary constraint to life.

On the basis of this indicator based on a supply side approach of defining water scarcity, Gujarat is a "water stressed region" since the annual per capita freshwater availability is far below 1.700 m^3 (1.321 m^3 in 1991). It will become a water-scarce region in the coming years since this availability of water might drop below the level of 1.000 m^3 per annum (Indian Institute of Rural Management, 2000, p.15).

"The United Nation's Commission on Sustainable Development defines water scarcity in terms of the annual withdrawals as a percentage of total freshwater resources available in an area. According to this criterion, if the total annual withdrawals represent more than 40 per cent of the annual renewable freshwater, the region is said to be water scarce. By this criterion also, Gujarat is water scarce as both surface and groundwater withdrawals are far exceeding the 40 per cent limit" (IRMA, 2000, p.16). If this situation affects both urban and rural areas, this phenomenon becomes more marked in towns at every new drought.

The recurrent phenomenon of drought

Since the 17th century, a major part of Gujarat undergoes a long serie of cyclic droughts, in average once in every five years: therefore, these are not new or unexpected phenomenon. After three consecutive droughts from 1985 to 1988, this State faced in 1999 one of the most severe drought of the past century. Scanty and irregular rains led to a severe drought during the summer of 2000. Some 25 millions people were affected and more particularly women, children and the poorest part of the population. "Some 9.500 villages, 4 metroplotain cities and 79 towns faced acute water shortage for basic human survival – drinking and basic human hygiene and livestock" (IRMA, 2000, p.4). Despite its efforts, the State did not manage to assure the supply of water for the people and the animals in affected areas. A mission comprising representatives of UNICEF, UNDP and Action India was formed in May 2000, on a request from the Government of Gujarat and attributed the severity of drought in the State to two main reasons (IRMA, 2000, p.5):

- the non recognition of the economic value of water ;
- the deficiencies in managing the water supplies and demand.

2.2.2 Present solutions to water scarcity

The over-exploitation of undergroundwater resources and their consequences

If the groundwater resources constitutes respectively 77% and 50% of the freshwater supply of the rural and urban areas, the large share of this renewable resource is consumed by the irrigation system; the main agricultural and irrigated regions being North Gujarat followed by Saurashtra, the south and the centre of the state. Several factors have encouraged the exploitation and the waste of groundwater: the absence of any property right regimes clearly established, the absence of institutional financing for the construction of wells, the high subsidy for electricity for the pumping of deep aquifers and the massive electrification of rural areas.

The depletion of groundwater levels is both the cause and consequence of water scarcity in Gujarat. We can differentiate the long-term depletion and the seasonal one. The long-term depletion is the result of an uncontrolled withdrawal of groundwater at rates that exceed the rates of natural replenishment over long periods of time. This is the situation of alluvial regions of North and Central Gujarat such as the Ahmedabad district. Their over-exploitation leads to exponential increases of both pumping depths and of the unit extraction cost of water (0.50 kilowatt-hours/m^3). Finaly, the rapid decrease of bore-wells yields reach levels that are not economicaly profitable (IRMA, 2000, p.33).

A report of the Gujarat Ecology Commission points out that groundwater extraction has increased by a 104% within two decades,1978-1997 (Gujarat Ecology Commission, 2000). Thus, in Mehasana district where the electricity tariffs are highly subsidised, farmers pump water from a depth of 800-1000 feets leading to a bore-wells depletion at a rate of 3 metres per annum (IRMA, 2000, p.33). This anarchical exploitation of groundwater led the Government of Gujarat to classify the districts according to the level of their water tables. In 1997, the Ahmedabad district was classified as "dark", since the gross annual withdrawal exceeded 90% of the usable annual recharge. This situation is likely to worsen : 87% of the

State's municipalities rely on groundwater for their supply (Gujarat Ecology Commission, 2000).

The excessive recourse to groundwater leads to a deterioration of the water quality. This deterioration has two manifestations:

- first, the increase of fluoride level resulting from an excessive withdrawal of groundwater from deep aquifers;
- second, the increase of salinity levels due to excessive withdrawal from coastal aquifers. The hydrostatic imbalances between freshwater aquifers and seawater are the consequences of this situation. The Total Dissolve Solids (TDS) levels in groundwater far exceeds the permissible levels for irrigation and make the water improper for many uses. This situation is all the more worrying than the arid regions of Kutch and Saurashtra constitute the essential part of the coastline of Gujarat (1.125 km) and the longest coastline (1.600 km) of the country (one third of it).

The excessive fluoride and water salinity are a major source of concern for public health. This situation which is likely to worsen may constitute an important cost for the society, in the mid or long run.

The large dams policy

- The current exploitation of surface water in Gujarat

Gujarat is divided into two zones separated by the Sabarmati river : a "water rich" area, south of the Sabarmati and "water scarce" region, north of the Sabarmati. The three perenial rivers (Narmada, Tapi, Mahi) located in the southern part of the state bring a significant quantity of water. (Gujarat State Drinking Water Infrastructure, 2000, p.12). The state has given the priority to the construction of surface water reservoirs, so as to tap the rivers and distribute the water for irrigation or domestic purpose. The main rivers are regulated by a series of dams and weirs (GSDWI, *op.cit.*, p.12) which has an impact on regions located downstream of the rivers and deprived of their flows. The subsequent degradation of the estuarine ecosystems leads to salinity in coastal areas as well as to a change of patterns in erosion and sedimentation and to a loss of mangroves.

To illustrate this impact in the upstream part of the estuaries, the Gujarat Ecology Commission points out the important decrease of the areas of lake, ponds and tanks in the Gulf of Khambhat from 1965 to 1975. These traditional water sources used to be a major lifeline in the arid, semi-arid and coastal parts of the State. "The failure of the centralised water supply schemes have once again rejuvenated interest in reviving the traditional sources of water, largely through check dams and other watershed management activities" (Gujarat Ecology Commission, 2000).

- The cost of Narmada

In continuation of the centralized policy of water resources development that began during the British colonization, after the Independence, the decision was made at the federal level to import Narmada water, one of the major rivers of the country, in Gujarat. The essential part of this river flows through Madhya Pradesh, skirts the north of Maharashtra; it reaches Gujarat and empties at Bharuch into the Arabian sea. The construction of dams inherent to this project will lead to the displacement of entire tribal communities of the neighbouring states of Maharashtra and Madhya Pradesh.

The foundation stone of a dam on the Narmada river was laid in 1961 by Nehru. It was the starting point of the building of a long list of large dams comprizing the Sardar Sarovar dam which is at the heart of a polemic. The project consists in having step reservoirs thanks to the building of 3.200 dams along the river and its tributaries.At the end of the day, "the Sardar Sarovar in Gujarat and the Narmada Sagar in Madhya Pradesh will, between them, hold more water than any other reservoir on the Indian subcontinent" (Roy, 1999, p.18).

The World Bank decided to finance the lynchpin of the Sardar Sarovar project, without any evaluation of the financial, human and environmental costs of the dam. But, an independent review appointed by the World Bank published in 1992 had unequivocal and unexpected views : "We think that the Sardar Sarovar Projects as they stand are flawed, that resettlement and rehabilitation of all those displaced by the Projects is not possible under prevailing circumstances, and that environmental impacts of the projects have not been properly considered or adequately adressed. Moreover, we believe that the Bank shares responsibility with the borrower for the situation that has developed ... it seems clear that engineering and economic imperatives have driven the Projects to the exclusion of human and environmental concerns... India and the states involved... have spent a great deal of money. No one wants to see this money wasted. But we caution that it may be more wastefull to proceed without full knowledge of the human and environmental costs... As a result, we think that the wisest course would be for the Bank to step back from the Projects and consider them afresh"(Morse and Berger, 1992) . Then, the Bank withdraw its support to the project.

According to Roy (1999), this project considered by the Indian Government as the "most studied project in India" lacks of a global approach, since there is a strong willingness of the State to favour :

- (1) the water supply of the urban areas at the expense of the rural ones;
- (2) the exogenous solutions to local ones.

In addition, she criticises the past diversions of the Sabarmati and Mahi rivers for supplying the Ahmedabad and Kheda districts as far as the arid areas of Kutch and Saurashtra haven't benefited from these projects. Also, she doesn't believe in the government willingness in "quenching the thirst of parched throats in Kutch and Saurashtra", since there was "no mention of drinking water for villages in Kutch and Saurashtra, the arid areas of Gujarat" (Roy, 1999, p.22).

The human cost resulting from the sole construction of the Sardar Sarovar dam is so enormous that the number of displaced families was constantly revised. From 6.000 families (1979), to 12.000 (1987) and 27.000 families (1991). Later, in 1992, the government aknowledged that 40.000 families would be affected. In 1999, according to the Narmada Bachao Andolan, the estimation was around 85.000 families - or half a million people deprived of their land.

Roy (1999) notes that the major drawback of this kind of infrastructure is that the purposes (irrigation, power production, and flood-control) conflict with one another. She argues that once the project will be completed, the scheme will produce only 3% of the production forcasted, about 50 megawatts. “Finally if you take into account the power needed to pump water through its vast network of canals, the Sardar Sarovar Projects will end up consuming more electricity than they produce” (Dharmadhikari, 1995).

After the water losses due to evaporation, the illegal pumpings on canals will remain the ultimate beneficiaries of the remaining share of water. They will be the influencial communities of the districts mentioned above, the urban centres, the industrial activities and the intensive crop areas. Finally, the arid and poor regions of Kutch and Saurashtra will collect the remaining water...

Alternative Solutions : Rainwater Harvesting

Since the urban population is growing at a much faster rate than rural populations, the imbalance of water repartition between the urban and the rural areas is likely to go on or increase in the short-mid run. This phenomenon will be amplified at the costs of rural areas due to the limited local sources of water in the cities and the exponential demand for water as a consequence of urban households’ rising income levels.

During summer, the local daily press regularly reports the conflicts between the inhabitants in villages or towns such as Rajkot to collect their share of water at the public standpost or at the well. We can add to this picture, the peasants’ irritation whose water is diverted by the government following the failure of monsoon to quench the thirst of urban dwellers. Under difficult climatic circumstances, the government gives itself the right to adopt draconian measures to supply the towns in water. In 1999 and 2000, a significative share of the Mahi-Kadana canal destinated to the irrigation of the paddy-fields of the region of Kheda was diverted in Ahmedabad and Baroda. The farmers affected by this arbitrary situation in 2000 had finally taken into rioting (IRMA, 2000, p.35).

Regarding Ahmedabad, the White paper for water in Gujarat gives a clear picture of the water supply situation : "In Ahmedabad city, the areas that are not covered by the Ahmedabad Municipal Corporation come under the jurisdiction of the Ahmedabad Urban Development Authority. In these areas, the domestic water supply is to be provided through the *Gram Panchayats.* But, given the dramatic increase in the population and the mushrooming of the multi-storeyed flats in the city outskirts, the *Gram Panchayats* are not able to provide the requisite water supply to the households residing in these areas. In view of this, the societies maintain their own bore wells. However, breakdown of these systems is very common, resulting from excessive draw down in water levels, collapse of well packing, burning of motors etc. In such circumstances, the private societies have to look for other sources of water supply" (IRMA, 2000*,* p.35).

In case of insufficient water or absence of individual access to water, the rainwater harvesting system is an alternative solution for the households, both in urban and rural areas. This rainwater can complement the existing water supply system and reduce the pressure on a system which is over solicitated. In this regard, the individual rainwater harvesting cisterns located in the Old city of Ahmedabad constitute an additional system to have access to water.

The following sections present a description and analysis of the water situation in Ahmedabad. After defining the profile of the city in terms of administrative organization, of population and of the existing water supply system (3.), we will present the methodology (4.) and main results (5.) of the empirical study conducted in the Old city which focused on the households'opinions and behaviors on the existing and the alternative water supply systems in the Old city area.

3. WATER SUPPLY IN AN URBAN SEMI-ARID AREA: THE CASE OF AHMEDABAD

3.1 Profile of Ahmedabad

3.1.1 Perimeter (ExhibitI - Ahmedabad District Map)

From a global perspective, there are four concentric circles defining the population in the Ahmedabad area (cf. Table I). According to the perimeter, the population in 2001 varies from 5 808 378 (District) to 4 214 369 (Ahmedabad Urban Authority), 3 690 305 (Ahmedabad + Outgrowths) or 3 515 361 (Ahmedabad Municipal Corporation).

Table I – Ahmedabad: Various areas and population, 2001

Perimeter	*Area*		*Population*
	Sq.km.	*Hectare*	**2001**
Ahmedabad Municipal Corporation (AMC)	***190.15***	***19,015***	***3,515,361***
Ahmedabad + Outgrowths	*234.15*	*23,415*	*3,690,305*
Ahmedabad Urban Agglomeration (AUA)	*310.00*	*31,000*	*4,214,369*
Ahmedabad Urban Development Authority (AUDA)	*1,294.65*	*129,465*	
Ahmedabad District			*5,808,378*

Source: *Census of India 2001, Series-25, Gujarat, Provisional Population Totals, Rural-Urban Distribution*, Directorate of Census Operations, Ahmedabad, 2001.

Ahmedabad District

The overall district population is 5 808 378. This population is mainly urban (4 652 035), owing to the demographic weight of the town of Ahmedabad. A 20% of the population lives in rural areas (1 146 343 persons). The district is a main administrative division that includes the Ahmedabad agglomeration, small towns such as Mandal and villages.

Ahmedabad Urban Development Authority (AUDA)

It includes the area of the AMC and 163 villages and towns. The fast developing western fringe of Ahmedabad is under its jurisdiction. But only part of the Ahmedabad District area falls within the AUDA limits.

Ahmedabad Urban Agglomeration (AUA)

Due to the rapid expansion of the city towards the West and East, several villages and towns have developed close links with Ahmedabad City. These areas are treated as Ahmedabad Urban Agglomeration by AUDA.

The Census of India defines A.U.A. area as a "contiguous urban spread consisting of a core town and adjoining towns and outgrowths". It includes the Ahmedabad Municipal Corporation (AMC), seventeen outgrowths, one cantonment board, three Nagar Panchayats[4] (NP) or towns, seven Gram Panchayats[5] (VP) or villages. These towns and villages are mostly situated in the northern and western outskirts of the city.

Outgrowths

Seventeen outgrowths[6], representing an area of 44 sq.km and a population of about 175 000 persons, essentially located in the western and southern vicinity of the town constitute a first circle of agglomerations outside the AMC limits. Due to their geographical proximity, the probability of their incorporation to the town is foreseeable in the long run.

Ahmedabad Municipal Corporation, (AMC)

The city perimeter has expanded from 5,7 km² in 1872 to 190,15 km² in 2001. Its major and last extension dates back to 1986, doubling its initial perimeter, with the addition of the eastern periphery. The previous limit covered an area of 98 km².

AMC has 43 "election wards" and is spatially divided into five zones (North, South, East, West and Central). This perimeter constitutes our town of reference for the study of water consumption: 19 000 ha. for a population of 3,5 millions in 2001.

---

[4] The Nagar Panchayats are: Ranip, Ghatlodiya, Kali.

[5] The Gram Panchayats are: Thalrej, Memnagar, Vejalpur, Makarba.

The Old City

It is the historical core of Ahmedabad, where the city was established five centuries ago. Located at the geographical centre of the city, the Old City is spread over 7.46 km². Its population was 372 526 in 2001, i.e. 11% of AMC population. It is divided into six election wards: Khadia (ward 1), Kalupur (ward 2), Dariapur (ward 3), Shahpur (ward 4), Raikhad (ward 5), and Jamalpur (ward 6).

3.1.1 Population

Past and Present situation

As can be seen from Table II, there has been a constant period of high growth of the population within the AMC limits, the average growth rate being 3,4% per annum, between 1931 and 1971[7]. This trend culminates in 1941 with an exceptional rate of 4,4% that can be partly explained by the incorporation of a new area doubling the initial perimeter. A similar phenomenon is noticeable in the 1981-91 decade, after an extension by half of the city area in 1986, with the difference that a slow annual growth rate (3,4%) and a high density, equivalent to the ones of the 1872 and 1881, characterise the 1981-1991 period.

In the present decade (1991-2001), the population keeps on increasing while the annual growth rate follows its declining trend (2%).

---

[6] The Outgrowths are: Asarwa, Naroda, Nikol, Rakhial, Odhav, Bag-e-Firdos, Shahwadi, Gyaspur (part), Maktampur, Okaf (part), Chenpur, Bodakdev, Muthiya, Vastral (part), Ramol (part), Hatijan and Vatwa.

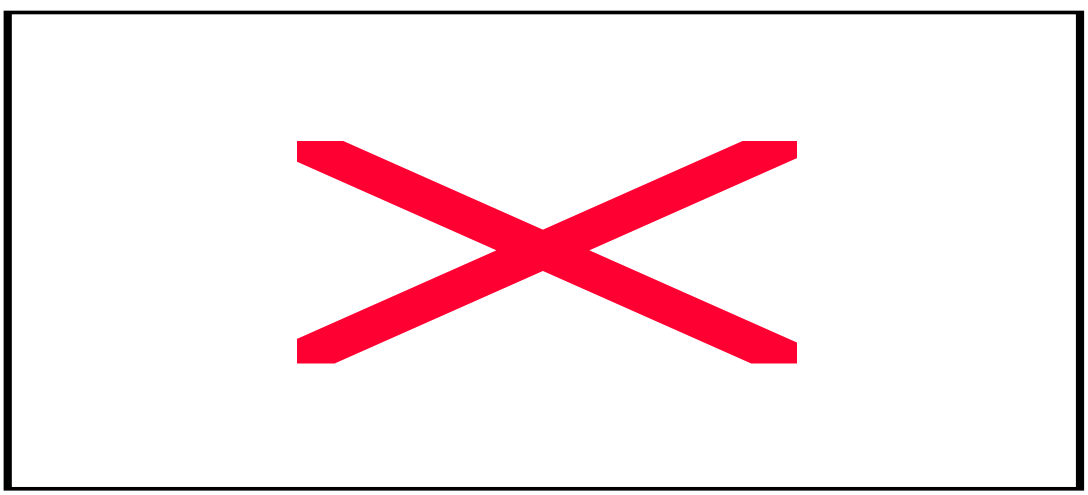
[7] Assuming an exponential growth along the period.

Table II – AMC: Population, Growth Rate and Density (1872-2001)

Census	Area		Population	Pop. Growth (%)		Density
Year	Km²	Hectare		/ period	/ year (*)	(pers./ha)
1872	5.72	572	119,672	-		209
1881	5.95	595	127,622	6.6	0.72	214
1891	11.42	1,142	148,412	16.3	1.52	130
1901	14.93	1,493	185,889	25.3	2.28	125
1911	23.08	2,308	216,777	16.6	1.55	94
1921	23.96	2,396	274,007	26.4	2.37	114
1931	25.29	2,529	382,768	39.7	3.40	151
1941	52.47	5,247	591,267	54.5	4.44	113
1951	52.47	5,247	837,163	41.6	3.54	160
1961	92.98	9,298	1,149,918	37.4	3.23	124
1971	92.98	9,298	1,585,544	37.9	3.26	171
1981	98.15	9,815	2,059,725	29.9	2.65	210
1991	190.15	19,015	2,876,710	39.7	3.40	151
2001	190.15	19,015	3,515,361	22.2	2.03	185

(*) Assuming an exponential growth along the period

Source: *Census of India 2001*, *Statistical Outline of Ahmedabad City 1998-99*, Planning and Statistics



Source: Department, Ahmedabad Municipal Corporation, Ahmedabad.

Future population

It has been assumed that in the coming decades the population will go on increasing but at a slower pace with a diminution of the annual growth rate. This phenomenon not only concerns the AMC area but also the outgrowths and the adjacent urban agglomerations. Thus, within the AMC limits, the annual growth rate is assumed to change from 1,4% (2001-2011) to 0,96% (2011-2021). If the outgrowths' situation is quite similar but with higher rates (3,4% and 2,7%), it seems that the adjacent urban agglomerations will experience a moderate decrease of their annual population growth rates (3,4% and 3%).

3.1.2 Urban development

Spatial growth of the city over time

Ahmedabad was founded in 1411 by Sultan Ahmed Shah on the banks of the Sabarmati River that flows through the city from North to South. In 1487, a fort wall and 12 gates enclosed the city that was planned according to the Indo-Aryan tradition of a royal capital, with main roads passing through the centre and subsidiary roads separating localities. *Puras* or suburbs like the existing area of Kalupur (ward 2) were developing around the core of the town or on the opposite bank, like Navarangpura (ward 10). The insecurity during the Maratha period (1753-1818) and frequent communal riots led the inhabitants to live in cast-wise *Pols*[8] secured with gates.

After the British took over the administration in 1818, the city developed on both sides of the river. The eastern bank started concentrating industries, railway terminus and commercial activities in the vicinity of the existing residential areas. The expansion of the textile industry speeded up the growth of the city beyond its medieval fortifications. As a consequence to this urban pressure, the walls were finally pulled down in the beginning of the 20th century.

[8] The *Pols* are mazes of narrow lanes with two, three or four storied wooden houses abutting them in a very compact arrangement. They are a special feature of the Old City of Ahmedabad.

From 1870 till the early sixties, the construction of several bridges across the Sabarmati accelerated the residential development and later on, the commercial activity on the western side of the river. A significant phenomenon in the last decades is the multiplication of commercial centres and apartment resort in the western part of Ahmedabad.

Population density and Type of housing *(ExhibitIII – AMC Population Density Map)*

The analysis of the ward-wise density of the AMC gives a good understanding of its historic evolution. Indeed, the highest population densities are situated within the limits of the ancient walled city; the average density in this area being 466 persons per hectare and the highest being 928 persons per hectare in Dariapur (ward 3). Another high concentration of inhabitants is at the Northeast of the Old City, i.e. the wards of Asarva (ward 19), Naroda Road (ward 20) and Saraspur (ward 21) concentrating some slums. This type of housing is also found in the East where the textile and ancillary industrial estates are located. These areas attracted the workers in these activities and consequently the density of this eastern periphery increased.

Average density zones are in the northern fringes as well as in part of the South and East of the city. There the average density is 174 persons / km².

The West of Ahmedabad as well as the south-western, southern, eastern and north-eastern periphery are low density areas.

3.1.3 Geographical approach

This approach lies in comparing the demographic evolution of two distinct parts of the city under the AMC limits, the Old City and the "Rest of Town", from 1921 onwards. Its purpose is to put the emphasis on the movement of population from the Old City to the "Rest of Town".

Old City

The population and density of the Old City have increased till 1971 and have reached their maximum in the same year (480,735 inhabitants and 644 persons per ha.). Then, the population growth rate decreased and became negative. After a high decrease of its growth rate and density in the 1981-1991 decade (-1,73% and 534 persons per ha.), the population experienced a moderate diminution from 1991 to reach 372,256 in 2001. As the Old City remains the most densely populated area of Ahmedabad, its density, which doubled between 1921 and 2001, has been following a constant decline since 1971: from 644 inhabitants per ha. in 1971 to 499 in 2001 (cf. Table IV).

Table IV - Old City area: Population, Growth Rate, Density

Census	Area		Population	Pop. Growth (%)		Density
Year	Km²	Hectare		/ Period	/ Year (*)	(Pers./ha)
1921	7.46	746	185,552	-	-	249
1931	7.46	746	244,792	31.9	2.81	328
1941	7.46	746	314,396	28.4	2.53	421
1951	7.46	746	393,941	25.3	2.28	528
1961	7.46	746	459,535	16.7	1.55	616
1971	7.46	746	480,735	4.6	0.45	644
1981	7.46	746	474,223	-1.4	-0.14	636
1991	7.46	746	398,410	-16.0	-1.73	534
2001	7.46	746	372,256	-6.6	-0.68	499

(*) Assuming an exponential growth along the period.

Source: *Statistical Outline of Ahmedabad City (1998-99)*

Rest of Town

The population of the "Rest of Town" (i.e. outside the Old City, within the AMC limits) increased constantly from 1921 to 2001, with an average population growth rate of 4,5% per year. During the same period, the density increased on a regular pace, except after each significant extension of the AMC limits: since the perimeter increased by 2,5 between 1931 and 1941, the density slightly decreased (62 persons per ha. in 1941). The same phenomenon happened during the 1951-1961 and 1981-1991 decades, when the perimeter of the city almost doubled each time. If we exclude this last period, we notice that there hasn't been a significant variation in the density between 1971-1981 (175 persons per ha.) and 1991-2001 (172 persons per ha.). Moreover, if we disregard the 1981-1991 decade, the population growth rate is continuously decreasing from 1971 (4,8%) to 1981 (3,6%) and 2001 (2,3%).

Table V - Rest of town (outside the Old City): Population, Growth Rate, Density

Census Year	Area Km²	Area Hectare	Population	Pop. Growth (%) / Period	Pop. Growth (%) / Year (*)	Density (Pers./ha)
1921	16.5	1,650	88,455	-	-	54
1931	17.83	1,783	137,976	56.0	4.55	77
1941	45.01	4,501	276,871	100.7	7.21	62
1951	45.01	4,501	443,222	60.1	4.82	98
1961	85.52	8,552	690,383	55.8	4.53	81
1971	85.52	8,552	1,104,809	60.0	4.81	129
1981	90.69	9,069	1,585,502	43.5	3.68	175
1991	182.69	18,269	2,487,300	56.9	4.61	136
2001	182.69	18,269	3,143,105	26.4	2.37	172

(*) Assuming an exponential growth along the period.

Source: *Statistical Outline of Ahmedabad City* (1998-99)

Shift of the population from the Old City to the "Rest of town"

The urban development of the western side of the Sabarmati River in the beginning of the 20th century, which attracted the emerging middle class, is one of the main reasons explaining a shift of the population from the East towards the West. Two major events have fostered this trend: the collapse of the textile industry (East) in the eighties as well as the transfer of the industrial activity to the eastern periphery. The commercial development to the detriment of housing has brought a number of problems in the Old City, that affected seriously the quality of life: high traffic, infrastructure deterioration, dilapidation of housing stock and lack of open space. The subsequent decrease of the population lead to the multiplication of warehouses disturbing the remaining neighborhood.

Moreover, since the area has a long tradition of communal conflicts, which is still alive, the risks inherent to frequent riots (1992, 2002) and frictions linked to promiscuity are additional factors to leave the place. Therefore, the western part of Ahmedabad attracts today most of the investments from both public and private actors. In the coming years, the population of the "Rest of Town" will increase while its population growth rate is likely to follow its declining trend, due to the shift of residents from the centre to the fringe areas.

3.2 The existing Water supply system: Technical data

Most of the technical data required to understand the existing water supply system have been collected in the Water Supply Department of AMC, in June 2001. The information obtained is relevant for this period.

3.2.1 Institutional aspects

AUDA

Within the jurisdiction of Ahmedabad Urban Development Authority, 163 villages, towns and municipals councils are responsible for service provisions: the Gujarat Town Planning and Urban Development Act of 1976, under which AUDA was created, does not mention direct responsibility for the provision of water, although the execution of works is among the attributions of the AUDA. For planning, design and implementation of water supply, AUDA relies on private agencies. Finally, this entity is more a co-ordinating agency than an implementing one.

AMC

The Ahmedabad Municipal Corporation is the technical operator and supply agency of the water services within the city limits. Provision of water supply, sewerage and drainage is a compulsory function of the Corporation stipulated by the Bombay Provincial Municipal Corporation Act of 1949 that provides the framework for its intervention. The following analysis will focus more specifically on the AMC water supply situation.

3.2.2 Production

The total daily production of water for AMC is 570 MLD[9]. The city is both dependent on surface water (300 MLD), from Mahi River through Raska weir and on ground water (270 MLD) from bore wells, located in various parts of the town[10]. Some 300 to 350 bore wells out of 410 are used daily[11]; the remaining ones are used alternatively, according to the needs.

Ground water is being extensively developed, through the tube wells, from deep aquifers for water supply in domestic and industrial sector. The withdrawal from private bore wells is estimated to 80 MLD[12]. Most of the industries, large establishments as well as housing societies supplement the public piped supply by drawing water from their own bore wells, all through the day and without any restriction, at a comparatively low cost. This is also the case of the western fringe of AUDA area, which mostly depends on ground water from private bore wells.

3.2.3 Supply: Network and Quality of service

Network

The water supply distribution is organized according to the existing five zones (North, South, East, West, and Central), although the network is not fully developed in the newly added areas in the North and South of the city. Each tube well station commands a certain area and the entire distribution system, the length of which is 2388 km., is interconnected[13].

---

[9] Million Litres per Day (equivalent to 1 000 cubic metres).
[10] AMC, Water Supply Department, Interview, May 2001.
[11] AMC, Water Supply Department, Interview, June 2001.
[12] CEPT (2001), *Rapid Environmental Impact Assessment of the Sabarmati River Front Development Project*, Ahmedabad.
[13] AMC (2000), *Statistical Outline of Ahmedabad City, 1998-1999*, Planning and Statistics Department, Ahmedabad.

Hours of supply

The official duration of supply in Ahmedabad is only two hours in the morning, from 6 to 8. Supply duration can differ from one location (getting more than four hours supply) to another (receiving water during less than two hours).

3.2.4 Non Revenue Water (NRW)

According to AMC, approximately 20% of 570 Millions Liters per Day (MLD) are lost before consumption, due to technical loss (leakage, seepage) or commercial one (unauthorized use). Such a level of NRW is usually found in towns located in developed countries (when the network is well maintained). Therefore, the figures given by the Corporation can hardly fit to the reality.

We assume that the NRW or total loss is 55% of the production of water of which 40% is technical (leakage, seepage) and 15% commercial (unauthorized use)[14]. Therefore, the consumption (billed or not billed) would be 60% of the production (15% of commercial loss + 45% of billed consumption), i.e. 342 MLD.

3.2.5 Coverage

According to the Census of India, in 1991, 88,2% of the households had an access to drinking water through the "Tap" and 11,7% through different sources (well, handpump/tubewell, river/canal, others). 68,8% of the taps was situated inside premises and 19,4% outside premises. In 2001, we assume that 90% of the households have access to the tap, which is for 71% inside premises and 19% outside premises (cf. Table VI).

[14] Losses are uncertain because the consumption itself is uncertain due to the absence of metering.

Table VI - Households per source of drinking water in AMC in 1991

Source of drinking water	Households	Percentage
Tap	521 690	88,2
> (Inside the premises)	(407 050)	(68,8)
> (Outside the premises)	(114 640)	(19,4)
Well	37 350	6,3
Hand pump / Tube well	21 275	3,6
River / Canal	230	ε
Tank	175	ε
Others	10 795	1,8
TOTAL	**591 515**	**100**

Source: *Census of India 1991, Series-7, Gujarat, Part VII, Tables on Houses and Households Amenities*, Directorate of Census Operations, Gujarat, Ahmedabad, 1991.

Individual connections

If we refer to this Census, a first assumption is that taps inside premises are individual.
If we assume that 71% of the population (2 495 906 persons) have an individual connection in 2001, on the basis of a total number of 246 239 connections, there are 10,1 persons per individual connection.

Public standposts

Based on the figures given by the Census (Table VI), we assume that in 2001, 19% of connections outside premises are public standposts supplying water to 667 919 persons. Since AMC estimates the total number of public standposts to 7 000[15], there are 95 persons per standposts.

To confirm our assumption that tap outside premises corresponds to public standpost, we can have the following reasoning: if we assume that in 2001, there are 100 persons per standpost, hence, 700 000 persons are supplied water by this mode i.e. 19,9% of the population. This figure is close to the percentage of households served by a tap in 1991 (19,4%) and confirms therefore that tap outside premises should correspond to public standpost. A study done in 1995 mentions that the Corporation supplied water to the slum dwellers through 3 100 standposts[16].

Shallow wells

A survey published in 2001 attests that shallow wells are not any more in use within the city limits due to rapid urbanization and low quality of water, except in "low income housing societies and slums, where assured supply of water does not exist"[17]. There, shallow wells like hand pumps are also used for drinking purpose. They are also found in some areas in the North West (Chandlodia, Ghatlodia), in the South West (Vasna/ward 8, Vejalpur, Sarkhej) and in the South (Vatva/ward 42, Isanpur/ward 43, Narol, Lambha).

Private Tankers

Private tankers have been operating in Ahmedabad since about 15 years. There has been a multiplication of their number due to profitability in this sector. Their major consumers are government offices, construction companies, etc. They are mainly located outside the AMC limits, in the AUDA area (Thaltej, Vasna and Memnagar) and they extract water from the wells located in the fields or purchase it from the farmers (Ladda, XXX, p.40-41).

3.2.6 Consumption

Domestic consumption

AMC declares that they provide 160 Litres Per Capita per Day (LPCD) to the population. This assertion is closer to basic overall calculations than it is to the consumers' reality: it doesn't take into consideration the non-coverage of 10% of the population and the technical losses, i.e. 40% of the production of water (227MLD).

Let us propose our own estimate: if we assume that 95% of the total consumption is for domestic purpose (326 MLD) and 90% of the population receive water from an AMC

---

[15] AMC, Water Supply Department, Interview, June 2001.

[16] Brijgopal, Ladda (1995), *Planning and Financing Urban Water Supply: A Case Study of Ahmedabad*. CEPT, Thesis, Ahmedabad, 390 p.

connection (3 163 825), the LPCD becomes 103. The total number of individual connections in 1998-99 is 246 239. Based on our assumption of served population by an individual connection, there is an average of 12,8 persons per connection. Here are the main characteristics of the domestic demand in 2001, as detailed above (cf. Table VII)

Table VII – Main Characteristics of Domestic Demand (2001)

Distribution Domestic-Non Domestic	**95%-5%**
> Domestic consumption	**> 326 MLD**
Coverage from a connection	**90%**
Connected Population (i.e. population receiving water from an AMC connection)	
- Population	3 515 361
- Connection rate (**)	90%
> Served population	**> 3 163 825**
Litre Per Capita per Day (LPCD)	
- Distribution of water	326 MLD
- Served population	3 163 825
> LPCD	**> 103**

(*) For checking this rate, we consider the served population as derived from the number of connection.

(**) In 1991, the rate was 88,2% (Census of India). We assume a slight improvement during the last decade.

Non-domestic consumption

According to a study achieved in 1998[18], light industrial, commercial and services activities representing some 6 000 consumers are metered, in contrast to a very small percentage of metered domestic consumption.

We assumed that 5% of the total consumption is non-domestic i.e. 17 MLD. And if we take the estimated production of private bore wells, the total non-domestic consumption is about 100 MLD.

Most of the industrial demand is not met by AMC (textile mills, railways, power plants, etc.)

[17] CEPT, p.14.

[18] Shashikant, Pandey (1998), *Spatial Decision Support System for Water Supply for Ahmedabad*. CEPT, Thesis, 65p.

3.2.7 Cost of water

The connection cost is Rs.1000. It has to be verified whether this cost varies according to the type of consumer and the perimeter or not. Figures related to the repartition of connections by type of housing were not available in AMC. Due to the absence of metering for domestic connections, billing of water is not based on consumption but on taxes fixed in relation with property tax. In consequence, the water and conservancy taxes are levied on the basis of area property.

Water Tax

- Residential properties are charged between 15-25% of the property tax, for area between 50-200-sq. m. and above; the minimum monthly rate being between Rs.12-Rs.17.50 according to the area;
- Non residential properties are charged between 15-22% of the property tax, according to the area; the minimum monthly rate being Rs.30-Rs.50 according to the area;
- "Special industries" are charged between 25-30%, with a minimum monthly rate of Rs.60.

Conservancy Tax

All properties are charged 18% of the property tax, with a minimum monthly rate of Rs.10. (residential) and Rs.15 (non-residential).

Meter Charges

In metered connections, residential, commercial and air-conditioned commercial properties are charged Rs.3, Rs.8 and Rs.20 per 1000 litres. Construction sites are charged Rs.20 per sq. m. of built up area.

The case of slums

In Ahmedabad, most of the areas with limited access to piped water are slums and urban fringes, where the population growth is more rapid than in other areas. Slums are required to pay Rs.4 and Rs.3 minimum per month as water and conservancy tax. In reality, in slums, most of the households do not pay property tax or have overdue for the last years[19]. As a result, "slum dwellers are provided water free of cost"[20]. Illegal connections are common and the prescribed minimum charge is not paid.

Other housing types have 20% population not paying taxes. In the case of bungalows and flats, taxpayers' percentage is higher than others.

3.2.8 Storage of water within households

Ahmedabad, as other Indian metropolis is characterized by heterogeneous consumption of water. Piped network mainly serves central areas of the cities. In these areas, the water supply is limited to few hours per day (two hours on an average in the Old City) and the quantity supplied differs from one location to another. As a consequence, a significant number of households use facilities to ensure continuous water supply. Over the times, in such a context, storage has been a practical response to the shortage of water. Today, this practice is found in different areas, without any distinction of social class or housing type. In various fringes of the town, several households privately construct overhead tanks and install motor pumps.

---

[19] Rajesh, Suhane (1997), *Dynamics of Water Supply Management System: a case of Ahmedabad*. CEPT Thesis, Ahmedabad, 77p.
[20] Op.Cit., p.33-34.

The Tanki, to compensate the unreliability of water supply

Within the Old City, the residents of *Chawls*[21] use small cistern called *Tanki* to collect the water supplied by the municipality in the morning time, generally from 6 to 8, for using it all through the day. This solution has been set up to compensate the unreliability of water supply.

The Tanka, to tackle the water scarcity

Another well spread water storage facility is the *Tanka* or individual underground cistern, based on the collection of rain water collected on the roof of private house. This existing old system, which is not any more utilized, can represent a substantial additional source of water from a local perspective, i.e. the *Pol* area of Ahmedabad. This system emerged to tackle water scarcity in this drought prone city. There are about 10 000 *Tankas* in the Old City and their storage capacity ranges from 25 000 to 50 000 litres. See Annextures:
A. Tanka Structure B. Street Map

3.2.9 Assessment of data

Due to the unreliability of some data provided by AMC (NRW, LPCD), part of the analysis related to the water supply situation is based on assumptions. These hypotheses are the result of comparison with other towns of the same size and level of development in term of water supply management.

No appropriate data were found in relation with income groups (size, income, consumption and connections).

[21] *Chawls* are single room row houses. They constituted an answer to the housing needs consecutive to the development of the textile industry.

3.2.10 Geographical approach

Old City

Although no data regarding the ward wise LPCD were available in the AMC, the high densities of population in the Old City presuppose that the availability of water per capita in that area is among the lowest of the entire city. Therefore, the rehabilitation of the *Tankas* in the Old City can be seen as a potential local answer to water scarcity in that zone.

Rest of the town

The significant shift of the population from the central zone towards the eastern and western part of the city reveals that both of these areas will see their water demand increase in the coming years.

Conclusion

The notion of water scarcity reveals three distinct situations: absolute scarcity (lack of sufficient water), poor timeliness (discontinuous distribution of water) and the combination of both situations. In the case of Ahmedabad, the second hypothesis seems to be predominant. In such a situation and from a local perspective, the alternative sources of water could constitute an answer and supplement the present system of water supply, which is unable to satisfy the needs of the inhabitants.

4 RESEARCH METHODOLOGY OF THE EMPIRICAL STUDY

To the best of our knowledge, detailed studies of the conditions of implementation of local water management in a specific case have not been developed. In that regard, the rehabilitation of the rainwater harvesting system in the Old city of Ahmedabad might constitute an interesting case study, as far as the *pols* are managed by *panchs*.

4.1 Identification and Operationalization of the Research

4.1.1 Definition of the research topic

Water scarcity in Ahmedabad is a tangible phenomenon when referring to the evolution of liter per capita per day (LPCD) during the past decades. This figure has decreased from 191 to 125 LPCD from 1971-72 to 1996-97, despite the increase of the volume of water supplied which has grown from 317 to 415 millions of liter per day (MLD) during the same period (IRMA, 2000). In spite of the decrease of its growth rates, the population will keep on growing from 2001 to 2021. Therefore, we can assume that this situation will lead to acute water supply issues to be managed by the municipal corporation supplying water in the city, particularly in the Western part of the city. From this diagnosis, one should think of alternative solutions of water supply in Ahmedabad, in a geographic and climatic context of water scarcity.

Like in many other Indian cities, water storage practices in Ahmedabad are a daily routine for the population, independently of the social class. Hence, the traditional rainwater harversting system , called *tanka*, mostly existing in the Old city, can fulfil two major functions: providing an additional source of water within the Old city, and reducing the pressure on the water demand from a local perspective. The saving in water would not be negligible since 90% of the population is supplied by a municipal connection, and since 95% of the water supplied by the municipality is used for domestic purposes.

Nowadays, t*ankas* are mostly unused by the inhabitants of the Old city. The use of the underground cisterns sets the question of their necessity. According to Zérah (1999), this necessity can be explained by the unreliability of water supply provided by the municipalities.

Her study conducted in Delhi has shown that three elements characterize the unreliability of water supply : discontinuity of supply, insufficiencies and fluctuations in pressure, incapacity to forecast the water supply service (shortages, seasonal variations…).

The objective of the research is therefore to describe both opinions and behaviors of households in Ahmedabad regarding the water supply system they are currently using and the rainwater harvesting system.

4.1.2 Research hypothesis

Under the hypothesis that the water supply system does not fulfil the needs of the population in a context of water scarcity, the *tankas* represent a useful source of water, particularly for non potable water which constitutes most of the total consumption. Indeed, on the basis of a 500 liters per day per household (5 people), only 6% of this consumption must be potable, that is 30 liters per day per household, or 6 LPCD (liter per capita per day). So the aim is to know to what extent and under which conditions the rainwater harvesting system can complement the current supply system, and to what extent the population is ready to use it. It is therefore important to focus on the quantitative as well as qualitative characteristics of both systems.

4.2 Framework of the Study

4.2.1 The type of research

The research is descriptive by nature because the primary objective is to describe a situation (the water supply situation in a given area). It is based on a survey conducted by means of a questionnaire.

The cross-sectional analysis was chosen for several reasons[22]. We know that water consumption practices and that the opinion of inhabitants regarding water supply systems are not phenomena that are exposed to large variations in a normal situation, that is in times

[22] According to Churchill (1991), there are two types of descriptive research: time series analysis and cross-sectional analysis. The first refers to a given phenomena observed at regular intervals of time on a permanent sample (panel), while the second provides a picture of the phenomena at a given moment.

where there are no exceptional conditions (climatic changes, natural disaster, change in sanitary conditions, modification of infrastructures). If Ahmedabad is still in some places under the shock of the Gujarat earthquake that happened in January 2001, the impact of the quake was not visible at the moment of the survey which started 10 months later. The reason for it is simple: the Old City was the less damaged part of the urban area.

4.2.2 Data collection methods and measurement instruments

(see Annexture C. – The Questionnaire: the Old city survey)

Data collection requirements on the situation of water supply in the city must be precised. To obtain information that would be less subjective as possible, it is necessary to have a proper understanding of the opinions and behaviors of the users of both systems, the water supply system and the rainwater harvesting system. It is also necessary to describe the sociodemographic status of respondents. Three 3 major domains were covered in the questionnaire:

- sociodemographic data;
- opinions and behaviors regarding the current water supply system
- opinions and behaviors regarding the rainwater harvesting system

Based of the literature review and on several qualitative interviews from households conducted prior to the design of the questionnaire, the following 7 categories of variables were described by 153 variables composing the questionnaire:

- description of the house, household, cast, education, occupation, income;
- access to water and level of equipment;
- daily consumption per household
- perceived quality of service;
- storage practices;
- maintenance practices;
- willingness to use the alternative system.

Questions asked are essentially multiple choice questions except several open questions when it was not possible to pre-define the possible choices to be mentioned by respondents. Linguistic issues were faced when designing the questionnaire since it was designed in

English and translated into Gujarati, the local language of Ahmedabad city. It was then pre-tested with 5 households and was slightly modified in accordance (e.g. regarding the understanding of certain expressions or regarding the identification of the housing unit which comprises several distinct households). The final version of the questionnaire was established in English, but it was administered in Gujarati.

4.3 Data collection, Processing and Analysis

4.3.1 Sampling design

(see Exhibit V- Map 5: localisation of the *pols* surveyed in the Old city)

Definition of the population and selection of the sample

The population targeted by the research lives in the Old City of Ahmedabad because the individual *tankas* for rainwater harvesting are essentially concentrated in the *pols* of this area. About 500 *pols* would exist in the Old City (Dupavillon, 2001). Considering that all the *pols* of the Old City do not all have *tankas*, it is necessary to localise those who do have *tankas*. The 2 *pols* that have been studied in the Franco-Indian Old city rehabilitation project were retained for this survey: *Akasheth Kuva no pol* (Akasheth) and *Jadha Baghat ni pol* (Jadha Baghat). The maps that have been drawn by the project team enabled us to localise the *tankas* inside each of the 2 *pols* (Direction de l'architecture et du patrimoine, 2001). Still the localisation of *tankas* remains partial since the number of *tankas* indicated in the maps is inferior to the one which was actually observed in the field study.

Studying 2 *pols* provided many advantages because their differences in many respects:
- the geographical location and the ward;
- the ethnic composition;
- the levels of education, of income and of professional activity.

Sampling unit and respondents

The sampling unit is the housing unit that may gather 2 to 3 households (enlarged family pattern). In the majority of cases, the respondent is a woman answering the questionnaire in the name of her household. The final sample is composed of 60 households equally split between the 2 *pols*.

The choice of the sampling unit is first based on the availability of a *tanka* in the housing unit because rainwater harvesting requires a *tanka* to store water. The questionnaire was therefore administered in priority to households who may use the rainwater harvesting system. Three types of rainwater harvesting systems were distinguished :

- the "operational systems" (OS): households that have a *tanka* and that are using it;
- the "non operational systems" (NOS): households that have a *tanka* but that are not using it because of their closing;
- the "non existing systems" (NES): households that do not have a *tanka*.

Sampling method

The sampling method is therefore non probabilistic. This method is the most adequate because we want to identify first the households whose rainwater harvesting system is operational, followed by the non operational systems and the non existing systems.

Therefore, a combination of snowball and convenience sampling was used to reached the relevant respondents. The snowball sampling relies on a sequential process by which the members of one group (e.g. the OS group) can be identified by a first member of the group. The repetition of the operation rapidly leads to the exhaustive identification of the households that have an operational system in the *pol*. In case of convenience sampling, information was obtained by interviewing people who accepted to answer the questionnaire. This approach is used to identify the non operational systems and the non existing system.

4.3.2 Data collection and analysis

Data Collection

The survey was conducted between late November 2001 and early January 2002. This is during winter season, and this must be remembered because the season impacts on the population's water needs. The *pol* of Akasheth was surveyed first, followed by the *pol* of Jadha Baghat.

The administration of the questionnaire took 45 minutes per household. It was administered by the researcher which allowed to minimize the potential bias that would result from insufficient training of local interviewers.

During the field study, no explicit resistance was expressed by the households in Akasheth regarding their participation to the survey. On the contrary, more resistance appeared in Jadha Baghat and we had to provide more explanations about the rationale of the survey. In the two *pols*, we informed the respondents that this study was undertaken with the back-up from the well known Indian Institute of Management Ahmedabad. In order to address the common mistrust towards civil agents of the municipality, we insisted on the academic aim of the study.

Data Analysis

Given the small size sample (60 households), we computed only straight tabulations and cross-tabulations on the main variables used in the questionnaire relating to socio-demographic dimensions, to the current water system and to the harvesting water system.

A marginal number of households have refused to collaborate to the survey, therefore a specific analysis of non responses cases is not necessary. This does not cast doubt on the validity of the results, even though the small size of the sample allows only for a preliminary analysis of the hypothesis of the research.

5 RESULTS AND DISCUSSIONS

5.1 Analysis of Socio-Demographic Datas

5.1.1 Household's composition

Seven houses out of ten are occupied by a single household. More than the half of the households interviewed declare that the house they live in has a number of occupants less or equal to 5 persons. This information confirms that the average households' size in India is 5 people (standard proposed by the National Council for Applied Economic Research) which suggests a trend towards the development of nucleus families.

5.1.2 Type of housing

More than half of the houses have 7 or more rooms, in other terms, these are family houses with multistorey buildings. Moreover, in 50% of cases, the number of rooms occupied by the households interviewed is inferior or equal to 3. Most of the households are the owners of their house.

5.1.3 The respondent

Cast belonging

Casts and sub casts the more represented in the survey are *Brahmins* and *Patels*. The first ones constitute almost half of the interviewees in Akasheth and the second ones the 2/3 in Jadha Baghat; the Indo-French study underlines effectively the social permanence of this *pol*, since only 3 to 4 houses are occupied by families from other casts (AFAA, 2001, p.62). This composition fits globally with the social structure of the *pols* which generally gather a population of a sole cast. *Vaishyas* is the second group of population represented in the sample of both the *pols*.

Sex, Age

Half of the interviewees are the heads of the family. Two thirds of the respondents are women answering for their household. They are mothers, daughters, daughters in law. In consequence, we have two equal age groups among the respondents: the 30-45 and the 46-60. These groups forms 8/10 of the respondents.

Duration of residence

The respondents whose birth home is the one where they live at the time of the survey form almost half of the population interviewed in each *pol*. Nevertheless, the inhabitants of Akasheth are more rooted in their *pol* compared to Jadha Baghat where the proportion of inhabitants with a duration of residence superior to 10 years is 2 times less than in Akasheth. Moreover, the new comers are only noticeable in Jadha Baghat where mobility is a perceptible phenomenon (1/10 of the respondents).

Education

Half of the respondents have a secondary education. In Akasheth, the number of persons graduated from higher education is the double compared to Jadha Baghat. These educated people represent almost half of the sample in Akasheth. This situation can be explained by the predominance of *Brahmins* in that *pol.*

Occupation

The households whose head of family is an employee account for 2/3 of the population interviewed in Jadha Baghat ; this is twice more than in Akasheth. At the other extremity of the hierarchy of occupations, one third of the respondents in Akasheth are professionals whereas in Jadha Baghat there is only one.

Annual income

One can note that ten households have an average income inferior to 10.000 Rs. in Jadha Baghat against only one in Akasheth. This situation puts the first *pol* towards the low income groups. In contrast, more than a third of the households interviewed in Akasheth have an income superior to 6.000 to 8.000 Rs. This population may be part of the medium class or the upper medium class. In between, we find an equal number of households earning from 2000 to 6000 Rs. This population represents half of respondents in each *pols*.

5.2 Households' Opinions and behaviors on the Existing Water Supply System

5.2.1 System of water supply

Most households have an individual connection to the municipal water network. If 4/5th have a single connection, 1/5th use two connections.

One exception must be noted about a household from Akasheth who lives in an apartment located in a building where the water supply depends on a deep well. Our study has not covered the households of the *pols* who live in buildings because the buildings do not match with the individual houses' typology retained in the study. But the number of buildings has been growing during the past years and it would be necessary to know how much population lives in such a housing within each *pol*.

5.2.2 Level of Equipment and Households' practices in Water Storage

The *tanki*

The storage by means of *tanki*[23] is a very common practice in the two *pols* : 5/6th of the households use a *tanki* and the average storage capacity is 442 liters.

The Buckets

The use of buckets is as common as the use of *tanki* since one uses the bucket to pour water in the *tanki*. The average containance of the buckets used is 9 liters. The households fill up an average of 216 liters stored daily. Only two households declare that they are not using buckets: they use an electrical device which is directly connected to the water tap. This illegal practice has been acknowledged in Akasheth. It should not to be considered as unique in both *pols*, eventhough we were exposed to it in a minority of cases during the survey.

[23] Generic term for a small cistern of water storage. It is generally installed near to the entrance of the house where the municipal connection stands.

Roof Cisterns

Water storage within cisterns made out of plastic and located on the upper floor of houses is a practice that generally strikes a foreigner's eye when visiting Indian cities. Here, a direct observation from the ground and from the upper terraces, does not show an important number of roof cisterns in the *pols'* houses. This is confirmed by the survey: ¾ of households do not use this storage device. Main reasons involved to justify this non use are essentially the absence of need and the impossibility to install a cistern on the roof. Then comes the cost of a cistern, this reason being mentioned mainly by households from Jadha Baghat. This corroborates the fact that ¼ of households who declare using this storage device live in Akasheth where income is higher.

The households using cisterns have been using it at least for the past 15 years in average, which is also the average number of years of using the *tankis*. The parallel is interesting. It would be useful to know exactly about the water supply situation when modern practices arose, independently of the fact that water storage has always been a major historical practice of inhabitants in this region.

Electric pumps

The electric pump is to the roof what the bucket is to the *tanki*: it enables to pour the water collected in the buckets on the ground floor into the cistern or any other device located on the upper floors,. As for the cisterns, our survey shows that 2/3 of households, among which more than 50% live in Jadha Baghat, don't use an electric pump. The main reason for not using it is the absence of need. The impossibility to install the pump is less mentioned, but the cost of a pump is the major resistance evoked by households in Jadha Baghat. This proportion is the same as for roof cisterns.

5.2.3 Daily consumption

Total consumption

The total water consumption and the variations of consumption from one season to another (winter/summer) are globally equivalent in the two *pols* (see Table VII- Selected Pols: Average daily consumption per households).

Table VII – ***Ahmedabad Selected Pols: Average daily consumption per households*** **(2001)**

Consumption (liters/day)	**Akasheth (AKA)**	**Jadha Baghat (JAD)**	**2 *pols* (AKA + JAD)**
SUMMER Estimates	360	380	370
WINTER Estimates	250	290	270
Survey (WINTER)	285	315	300

Source : Ahmedabad Survey (nov. 01/jan. 02).

The variations of consumption between the two *pols* in summer as well as in winter are marginal. Compared to households in Akasheth, households in Jadha Baghat consume a little more water in summer (20 liters, total 380 liters) and in winter (40 liters, total 290 liters). Given this proximity of consumption, it is justified to use the average of the two *pols* as the indicator. Therefore, the average consumption per households estimated in the survey is 370 liters in summer and 270 liters in winter, meaning the average seasonal variation is 100 liters.

Nevertheless, a rough estimate of water consumption necessary for different usages (cooking, washing dishes, bath, laundry, house cleaning) indicates a variation of consumption of 30 liters between summer and winter. We therefore have estimated that the average daily water consumption could be more than 30 liters, that is a total of 400 liters. The new consumption estimates per households per day are 300 liters in winter and 400 liters in summer.

Socio-demographic data show that ¾ of households are composed of a number of persons less than or equal to 5 people. If we consider the average of 5 people per households, there are 80 LPDC in summer and 60 LDPC in winter, the annual means being 70 LPDC over the year. This consumption estimate is consequently inferior by 33 liters when compared to our initial estimate of 103 LPDC presented in part one[24].

Consumption by type of usage

Below are the daily average consumption water by households as a function of different usage (see Table VIII- Selected *Pols*: Daily water consumption per households by type of usage).

---

[24] Cf.

Table VIII – ***Selected Pols: Daily water consumption per households by type of usage*** (2001)

Type of usage	Consumption (liters/day)
Drinking / Cooking	28
Washing Utensils	25
Bathing	70
Washing clothes	102
Cleaning the house	25
Other (toilets)	50
TOTAL	300

Source : Ahmedabad Survey (nov. 01/jan. 02).

Laundry constitutes 1/3 of daily water consumption of households. Water for drinking and cooking represents a minimum part of total consumption, less than 10%. The assumption that at least 6% of water consumption by households should be potable is here confirmed. Overall, 90% of total consumption are used for domestic purposes.

5.2.4 Quality of Service and Satisfaction of Users

The schedule for water distribution

Water distribution by the municipalities start à 5h45 and end at 8h15. Half of households that were interviewed get their supplies from 6 to 8 in the morning. The other half gets 15 minutes to 30 minutes less. The supply varies from one house to another for a certain number of reasons: a week pressure, the floor to be connected, the topographic situation and sometimes the use of electric pumps plugged on the neighbor's connection. This situation is not typical of Ahmedabad since Zérah (1999, p.92) notes a similar phenomena in Delhi. There does not seem to be any significant seasonal variation in the length of water distribution availability.

One must also note that 9/10th of households are satisfied with the schedule of water distribution. Besides, 4 households out of 10 would appreciate a longer length of water distribution, from 30 to 60 minutes more, preferably in the morning.

Water Pressure

50% of households estimate that water pressure is weak. The other half finds it normal. Reasons of this difference relate to the diversity of situations given the floor of housing, the topographic situation, the use of electric pumps in the same street, etc.

Quality of Water

50% of households find that the water is clear, the other half, mainly originating from Akasheth, find it unclear when civil servants from the municipality are doing work on the network. Among these, 50% say they have not notice any impurity in the water, 50% declare they have found solid elements in the water. Once again, it is the people from Akasheth who complain against this malfunction.

Ultimately, it seems that most households recognize the quality of the water supplied, this in spite of its brown color at the beginning of distribution or in spite of the presence of sediments in Akasheth. This suggests that the quality of water is not better there than in Jadha Baghat where income is lower. Zérah (1999, p. 101) shows the same result in Delhi where the quality of water is not always better in the richest neighborhoods.

Only 5 households out of 60 declare they have caught diseases relating to water usage. When asked about the quality of water delivered by the *tankis*, 3 consider that it is not clean, 1 that it is clean and 1 who does not know.

5.2.5 Using external sources of water supply

2/3 of households declare having enough water. 1/3 of them complement their water supply by external additional sources of water, that is the one taken from neighbors. Women and children are usually responsible for this task. If half of households use this strategy on a daily basis, the other half uses it during summer only. In both cases, this practice is done extensively, with several journeys taking place in the morning between the neighbors connection and the home. These journeys are made easier by the fact that the size of the *pols* is not very big, allowing for walking distance activities in narrow streets where few motorized engines come.

One must note in Akasheth the importance of the water quantity of households that are using this strategy : 206 liters per day and an average of 17 daily journeys to transport this water, which is twice of what was observed in Jadha Baghat.

2/3 of households have an average monthly income between 2000 and 4000 Rupees. Zérah (1999, p. 114) note that the time spent to storage goes down with the increase of income: "Households having less than 3500 Rs spend more than 40 minutes to this activity against 26 minutes for households having an income higher that 8000 Rs." Therefore the lower the income is, the more time is allocated to solve this issue of unreliability.

5.2.6 Current Price of Water and Willingness to Pay Water at the Real Cost

Given the fact that women represent half of our respondents, they usually don't know the amount of water bill to be paid for water consumption, this being even worse due to the annual payment basis. Still, after asking their husband, some of them have declared that the bill amounts to 150 – 200 Rs per year. It is a tax on water computed on the basis of the housing tax that varies depending on the surface of the housing.

To the question about the willingness to pay water at a unit tariff if an improvement of the quality of service was obtained, $4/5^{th}$ of households don't want to benefit from this type of service. The main reason given is the more expensive cost of the water that would result from it. Another motive is the impossibility to share water among neighbors. This response is not surprising given the importance of social links in the *pols* and of spontaneous mutual help behaviors among people living there. A third reason against modernized water supply is that it would mean stopping wasting water : an early morning observation shows the importance of water waste with water flowing into the houses and allowing women to wash the laundry more easily, without caring for the waste.

Still the unreliability of water supply has a cost for the households which includes monetary costs (maintenance of equipments) and opportunity costs in terms of time, that is the monetary valorization of time lost by the households when collecting water from neighbors, storing water in buckets, etc. (Zérah, 1999, p. 138).

5.3 Households' Opinions and behaviors on the Alternative Rainwater Harvesting System

5.3.1 Localization of Alternative Rainwater Harvesting Systems

An analysis of the operational state of alternative rainwater harvesting systems in the two *pols* shows the following (see Table IX):

- 1 household out of 10 has an operational system (OS);
- more than 1/2 have a non operational system (NOS);
- less than 1/3 of households don't have this system (NES).

Table IX – *Ahmedabad, Selected Pols: Operational State of Rainwater Harvesting System* (2001)

Operational State	Akasheth (AKA)	Jadha Baghat (JAD)	2 *pols* (AKA+JAD)
Operational System (OS)	7	3	10
Non Operational System (NOS)	13	19	32
Non Existing System (NES)	10	8	18
TOTAL	30	30	60

Source : Ahmedabad Survey (nov. 01/jan. 02).

A preliminary comparison of the state of systems in the two *pols* leads to the following conclusions:

- the OS identified by the Akasheth survey (7/30) represent more than twice those identified in Jadha Baghat (3/30);
- the share of NOS in each sample is higher in Jadha Baghat (19/30) than in Akasheth (13/30);
- the share of NES in each sample is more or less equivalent between the 2 *pols* (10/30 and 8/30).

See Annextures: D. Akasheth E. Jadha Bhagat

In spite of the small sample size, a first assumption is that the share of OS would normally be higher in Akasheth. Also the distribution of the systems by cast shows that the majority of households having an OS in Akasheth is composed of Brahmans (5/7). This cast is generally known for its conservatism, for the importance given to the concept of purity, especially in terms of water consumption.

The inhabitants who have an OS or a NOS think that these devices have been existing approximately for the last 130 years, and that their extensive use took place during about a century.

The OS are used accasionally in 9 cases out of 10. Only one household does not use it at all. The first reason given by the NOS households to explain why the rainwater harvesting system was abandoned is the introduction of modern water distribution systems.

5.3.2 Knowledge about the system

The cisterns used in the rainwater harvesting system are built with traditional materials. Walls are made up of bricks and mortar composed of river sand. They are then covered with plaster and lime.

The knowledge that households have about the materials used to build these old structures reflects a certain interest for the system, independently from the operationality of the system. Therefore, 5 households out of 10 who have an OS, and 6 households out of 32 who have a NOS know about the materials used in their cistern.

A container in aluminium or in terracota, commonly called *dhol*, is equipped with a roap to allow for water collection. The average storage capacity of individual cisterns is 25000 liters, and some contain even 50000 liters. Only 1 household among the OS and NOS group know exactly the capacity of their cisterns: 300000 liter for the OS and 10000 for the NOS. This single observation shows the magnitude of storage capacities.
Finally, only two households with an OS know the surface of their roof which captures rainwater.

5.3.3 Consumption practices

All the households who have an OS use rainwater exceptionally. In the majority of cases, the households can't say the quantity of water being used in these occasions. Here are some indications about the water usage:

- Weddings or religious celebrations (4/10);
- Religious rituals (2/10);

- Water scarcity (2/10);
- Civil works (1/10).

5.3.4 Quality of Rainwater

Unanimously, all the households having an OS or a NOS agree to say that rainwater is clear, smell-less, with a normal taste and without impurities.

One must say that the interior part of the cistern is in the dark, which forbids the development of chlorophyll propicious to the growth of weeds and germs. In stagnant water, the weeds are eaten by the germs; hence the absence of weeds makes it difficult for bacteria to grow (Singh, S.S., 2000).

5.3.5 Water Collection, Filtering and Purification Practices

Traditionally, water coming from the first rain is not collected. This practice allows for cleaning the roof from impurities. Besides, water is collected in function of the location of constellations called *nakshatras*. In the Indian calendar, the year is divided into twelve months, each month accounting for two *nakshatras*. According to Indian astrology, there are seven odd *nakshatras* considered as propicious for water storage in the *tanka*. According to certain predictions, during certain *nakshatras*, the germs and bacteria growth is minimal (Singh, 2000, p. 30).

Therefore it is interesting to compare the knowledge and the opinions of households having an OS about water collection, filtering and purification practices. Contrary to households from Jadha Baghat, households from Akasheth collect rainwater only after the roof being cleaned by the first rain. They also respect the principles of *nakshatras.*

According to the elders, water can be filtered by a cloth or a metal grid located at the entrance of the cistern. Inside the cistern, maintaining the quality of water can be done by pouring small quantities of alun, a mineral with antiseptic properties used in medicine[25]. In Cambay, a former port in Gujarat, the users of *tanki* are used to pour lime in the cistern after monsoon

[25] Information obtained during the field study from inhabitants known for their knowledge of the rainwater harvesting system.

season. The lime modifies the water pH. to make it more alkaline. Therefore bacterias that cannot survive in alkaline water are automatically eliminated (Singh, 2000, p. 25).

According to a popular belief, the water from the *tanki* is so pure that it does not require any treatment before it can be used. Therefore, the majority of households that have an OS declare they don't filter water at the entrance of the cistern because of its purity. Only 4 households use, by precaution, a cloth to filter the water at the entrance of the cistern. Similarly, the households do not purify the water inside the *tanki* because they think that the purity of water is properly maintained. By precaution, only one household pours alun in its cistern. Finally, when water has been extracted, the majority of households (7/10) do not purify it since they see it as pure. Only 2 households boil that water by precaution.

5.3.6 Maintenance of the Cistern

No precise field information was obtained relative to the maintenance of the storage cistern. Only the existence of a family specialized in the maintenance of this kind of system in the city of Diu (Gujarat) suggests that the cisterns should periodically be maintained[26]. Still, only one household with an OS confirms this information. Indeed, when summer comes, before the first summer rainfalls, water must be evacuated from the cistern. This operation requires members from the family to work half a day.

Apart from this exception, the majority of households (7/10) don't provide any maintenance to their cisterns, considering once again that the purity of water does not call for any special treatment to be given to the cistern.

5.3.7 Willingness to Use the Rainwater Harvesting System

Only 6 households having a NOS out of 32 wish they could use rainwater, essentially for domestic purposes, exclusive from cooking. When respondents don't know the approximate cost of the repair of the *tanka*, 4 declare to be ready to pay for it. The other two households who refuse to pay for the repair of the system accept the idea of a cofinancing approach.

[26] Information obtained by the Department in charge CONSERVATION DU PATRIMOINE in Ahmedabad municipality.

A deeper analysis of their storage practices shows that 7 households use their neighbors' connection to satisfy their water needs. The majority of them have a monthly income of less than 2000 Rs. Besides, 7 other households have invested in the buying of a roof cistern on their roof, among which 3 have a monthly income of less than 2000 Rupees.

5.4 Main Results of the study

The survey conducted in the Old city of Ahmedabad between November 2001 and January 2002 outlines several phenomena, intrinsically linked, relating to the opinions and behaviors of households regarding the current water supply system and the alternative rainwater harvesting system. Though exploratory by nature, the empirical study provides a useful preliminary empirical description of the two systems and of the opinions and behaviors of the households in terms of local water management.

Concerning the current water supply system, the survey suggests :

- a manifest water scarcity within a certain perimeter of the Old city which supports the hypothesis that the water supply system does not fulfil the needs of the population in a context of water scarcity such as in Ahmedabad;
- that unreliability of water does not affect all the households, and that it is independent from households' income;
- the existence of compensatory strategies developed by households to face the unreliability of the water supply (e.g. transporting neighbor's water);
- that developing these coping strategies generate costs, especially for the households (e.g. daily time allocation).

Concerning the alternative rainwater harvesting system, the survey suggests:

- the small number of operational systems for rainwater harvesting in the 2 *pols* studied;
- the important number of non operational systems that may be renovated;
- the near unanimity of inhabitants about the quality of rainwater;
- the willingness of some inhabitants to find alternative solutions to their water supply difficulties since the rainwater collection system presents the advantage to allow for the reduction of the unreliability costs, both monetary (maintenance of equipments) and opportunity costs in terms of time spent by the households in collecting water from neighbors, storing water in buckets, etc.

Apart from these economic aspects, the survey suggests that the alternative rainwater harvesting system, if renewed and effectively used, could allow households to reduce their dependence from the water supply system and to benefit from an additional water source, notably during summer and during dryness.

Finally, from the point of view of the water company (the municipality), the rainwater supply in a given sector of the city (the Old City) would allow for local sparing of the water volumes, this helping to minimize the global pressure currently existing on the water supply system.

5.5 Limits of the study

Our study suffers from several limits that must be mentioned. The first limit relate the empirical study and the methodological approach. The non probabilistic nature of the sample and the small sample size (60 households) do not allow for any generalization nor for the use of sophisticated statistics. A minimum of 100 households would have been necessary to improve data analysis.

The field study was conducted during the winter season therefore excluding the summer part of the year when consumption variations occur. Besides, the data collection approach is cross-sectional and cannot provide information about the evolution of households' opinions and behaviors over time, e.g. between winter and summer seasons.

The linguistic differences between the designed questionnaire (in English) and the administered questionnaire (in Gujarati) may have generated errors when translating the questions directly to the respondents during the interviews.

Finally, the questionnaire did not capture precisely the different factors (financial and psychological) that could hinder the rehabilitation and effective use of the rainwater harvesting system: if the economical cost of installing a *tanka* is obviously an important drawback, the psychological dimension of using an old water supply device that may be in contradiction with the wish to get water from modern devices should not be neglected. Using a traditional water system may also not be cognitively accessible given the fact that knowledge about traditional skills tends to disappear.

5.6 Future Research Avenues

Several avenues of future research can be suggested relating to the study of the rehabilitation of rainwater harvesting system in regions of water scarcity in Indian cities:

- The economic cost
- The psychological cost : the rehabilitation and effective use of this alternative water source would require a precise evaluation of the effective knowledge of inhabitants regarding the use of the system which seems to be currently low.
- The empowerment of local water supply management

6. CONCLUSIONS

The deficiencies of the water supply is a reality in various regions of the Indian subcontinent. Like many cities depending on ground water resources, the depletion of the water table in Ahmedabad reaches alarming levels: since 1965, this table would have decreased by 90 metres (National Institute of Urban Affairs, 1994). The search for new sources of water located outside the region is not a situation proper to Ahmedabad and Gujarat: the city of Madras in Tamil Nadu (south of India) gets its water from a source far from 200 km (Zerah, 1999, p.25). The large projects for the transportation of water represent an economic, social and environmental cost harmful to the development of entire regions in the short, mid and long run. This kind of infrastructures don't participate to a balanced development of the territory. Generally meant for urban areas, they hinders the development of rural areas that are less prosperous, but more numerous (about 70% of Indian population is rural).

Beyond the demographic pressure and the lack of resources affecting the water sector, the insufficiency and inefficiency of the investments largely explain the unreliability of the water offer (Zerah, op.cit., p.31). This unreliability is obvious in Ahmedabad and in particular in its Old city. It was observed on the field, during the survey on households' opinion on the current and the alternative water supply systems. When we refer to the comments of the interviewees, we find out that the consequences of this unreliability are both economical, social and psychological. Women, most of the time, are in charge of the domestic activities and are therefore the most affected by this situation.

An improvement of the water supply service which would decrease the time given by women to store water is not likely to happen because of heavy investments. In that regard, the rainwater harvesting system can constitute a potential alternative source of water which is likely to reduce the households dependency to the existing water supply system characterised by its unreliability. But the rehabilitation of the rainwater harvesting cisterns in the Old city of Ahmedabad raises a major issue : the local knowledge and governance of such water management systems in India. The rehabilitation of these alternative systems sets the question of the revitalization of social links and the type of knowledge and governance necessary to their effective use.

<u>**REFERENCES**</u>

Articles

Dharmadhikari, S. (1995), “Hydropower at Sardar Sarovar: Is it Necessary, Justified and Affordable? ”, in W.F. Fisher (Ed.) *Towards sustainable Development? Struggling Over Narmada River,* M.F. Sharpe, Armonk, New York, p.141.

Dupavillon, Christian (2001), “Ahmedabad, la belle endolorie”, in *Revue des Deux Mondes*, septembre-octobre, p.109-115.

Najimi, Abdul Wasay (1982), “The Cistern of Char-suq : a Safavid Building in Herat”, in *The Afghanistan Journal*, vol. 2, p.38-41.

Unpublished Articles

Ferrouki, Leyes (1998), *Project Proposal,* Ahmedabad, Indian Institute of Management.

Khadpekar, Vivek S. (2001), “Augmenting Ahmedabad’s Water Resources, A discussion note to complement the Gupta-Nema proposal”, Ahmedabad, Centre for Environment Education, 3 p.

Shah, A. Ashvin (1998), *Perspective on Water Management for the City of Ahmedabad,* Ahmedabad, Indian Institute of Management.

Unpublished studies

CEPT (2001), *Rapid Environmental Impact Assessment of the Sabarmati River Front Development Project*, Ahmedabad.

Singh, Sarbjit Sahota (2000), *Reviving an ancient wisdom: Tanka, a traditional roof top rain harvesting in the walled city of Ahmedabd, A pilot project undertaken by Ahmedabad Municipal Corporation,* Ahmedabad, 65p.

Books

Agarwal Anil, Narain Sunita (eds.) (1997), *Dying Wisdom. Rise, Fall and Potential of India’s Traditional Harvesting Systems,* State of India’s Environment, A Citizens’ Report 4, Delhi, Centre for Science and Environment, 404 p.

Ballabh Vishwa, Choudhary Kameshwar (1999), *Consultation Workshop on Small Water Harvesting Structures: Technology, Institution and Management*, Anand, Institute of Rural Management, 44 p.

Churchill, G.A. jr. (1991), *Marketing Research: Methodological Foundations*, Hindsdale, Fifth Edition, The Drysden Press, 756 p.

Cullis Adrian, Pacey Arnold (1991), *Rain Water Harvesting,* London, Intermediate Technology Publisher.

Gillion, Kenneth L. (1968), *Ahmedabad, A Study in Indian Urban History,* Berkeley, University of California Press, 195p.

Maksimovic, Cedo (2001), *Les nouvelles frontières de la gestion urbaine de l'eau,* Paris, Presses Ponts et Chaussées, 448 p.

Mishra, Anupam (2000), *Traditions de l'eau dans le désert indien, Les gouttes de lumière du Rajasthan*, Paris, L'Harmattan, 173 p.

Roy, Arundhati (1999)*, The Greater Common Good,* Bombay, India Book Distributers, 76p.

Saglio-Yatzimirsky (dir.), Marie-Caroline (2002), *Population et développement en Inde*, Paris, Ellipses, 224 p.

Shankari Uma, Shah Esha (1993) , *Water Management Traditions in India*, Madras, PPST Foundations, 193 p.

Wittfogel, Karl (1964), *Le despotisme oriental, étude comparative du pouvoir local,* Paris, Editions de minuit, 1964, 672 p.

Zérah Marie-Hélène (1999), *L'accès à l'eau dans les villes indiennes*, Paris, Anthropos, Collection Villes, 192 p.

Governmental and Municipality sources

Ahmedabad Municipal Corporation (2000), *Statistical Outline of Ahmedabad City, 1998-1999*, Ahmedabad, AMC Planning and Statistics Department.

Census of India (1991), *Series-7, Gujarat, Part VII, Tables on Houses and Households Amenities,* Ahmedabad, Directorate of Census Operations.

Census of India (2001), *Series-25, Gujarat, Provisional Population Totals, Rural-Urban Distribution,* Ahmedabad, Directorate of Census Operations.

Direction de l'architecture et du patrimoine, Association française d'action artistique (2001), *Recommandations pour la conservation et la revitalisation du centre historique d' Ahmedabad,* Paris, 83 p.

Gujarat Ecology Commission (2000), *State Environmental Action Programme, Phase-I Summary Findings,* Baroda.

Gujarat State Drinking Water Infrastructure (2000), *Gujarat Jal-Disha 2010, A Vision of Healthy and Equitable Future with Drinking Water, Hygiene and Sanitation for all*, Ahmedabad, National Institute of Design, 110 p.

National Institute of Urban Affairs (1994), *Urban Environmental Maps of Delhi, Ahmedabad and Vadodara,* New-Delhi, National Institute of Urban Affairs, 186 p.

Sardar Sarovar Narmada Nigam Limited (1989), *Planning for Prosperity*, Government of Gujarat.

Unpublished Theses

Ladda, Brijgopal (1995), *Planning and Financing Urban Water Supply : A Case Study of Ahmedabad,* Ahmedabad, CEPT, 390 p.

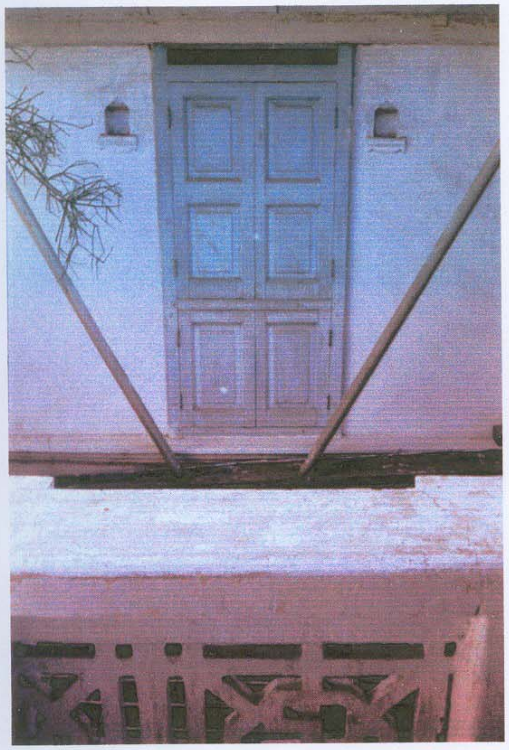
Pandey, Shashikant (1998), *Spatial Decision Support System for Water Supply for Ahmedabad,* Ahmedabad, CEPT, 65 p.

Suhane, Rajesh (1997), *Dynamics of Water Supply Management System, A case of Ahmedabad,* Ahmedabad, CEPT, 77 p.

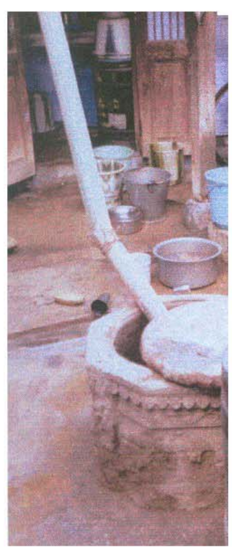
Other sources : Interviews

Ahmedabad Municipal Corporation, Municipal Commisioner, Ahmedabad, June 2001.
Ahmedabad Municipal Corporation, Water Supply Department, Ahmedabad, June 2001.
Ahmedabad Municipal Corporation, Statistics Department, Ahmedabad, June 2001.

Annexure A



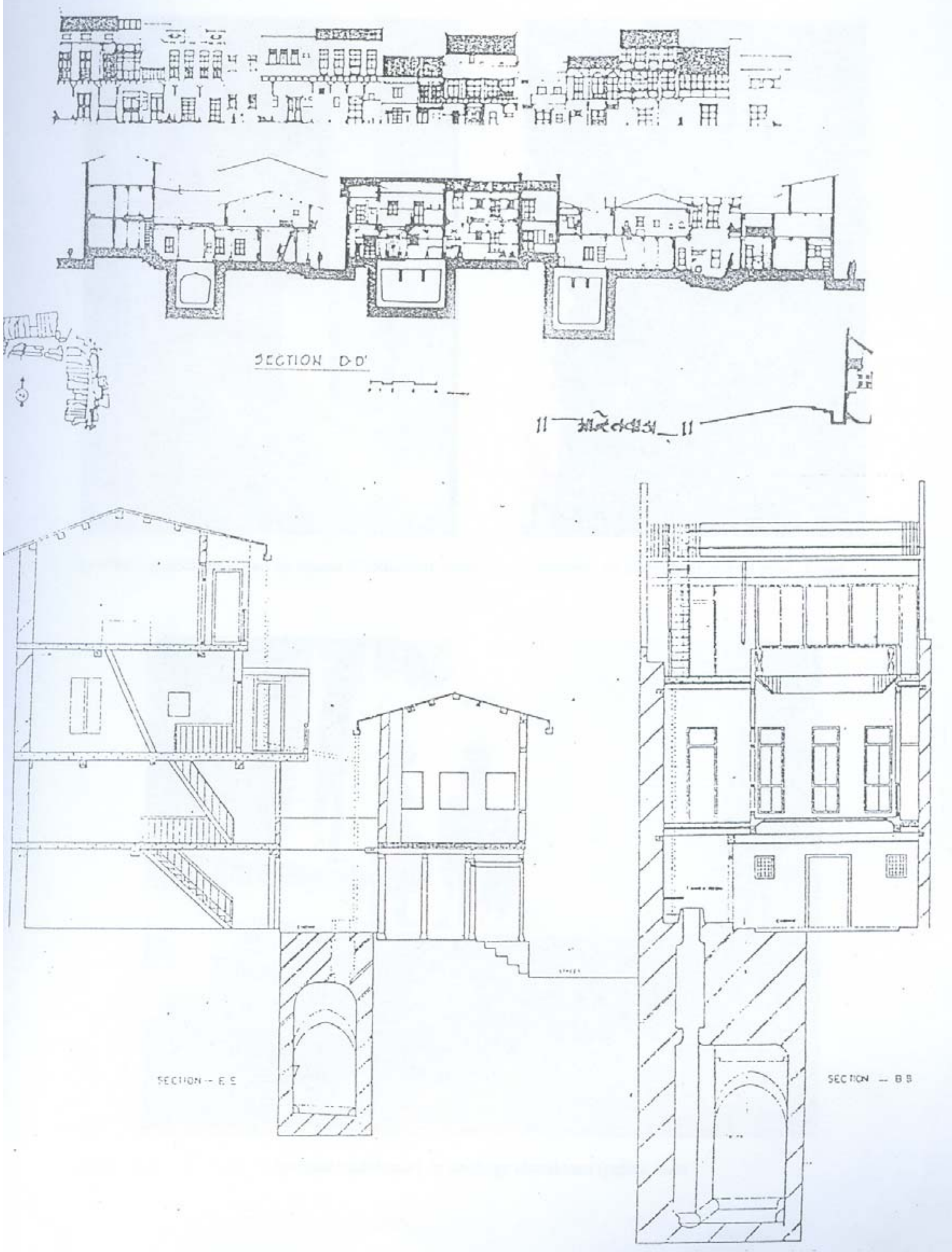
Descente de l'eau de pluie par le toit



Acheminement de l'eau de pluie dans la citerne

Annexure B

***Croquis* – Le système de récolte d'eau de pluie (Vue du *tanka*)**



Annexure C

Questionnaire

POL	Khadia :…	Number	Date	Time
Religion & Cast Seg,emt	……………. Non functioning RWHS Functioning RWHS Not having RWHS	Interviewee > Name > Address > Phone		

A. General Information – Mahiti

A.1 Neighbourhood Description – Padosh nu Varnan
Number of Houses :…
Number of Families :…
Number of People :…

A.2 Household Description – Gharana nu Varnan
Number of persons living under the same Roof
≤5 6-10 >10
Number of Households under the same Roof :
1 2 3 ≥4
Number of Persons within your Household
≤5 6-10 >10

A.3 Home Description – Ghar nu Varnan
Number of Rooms within the Dwelling
≤3 4-6 ≥7
Number of Rooms occupied by your Household in this dwelling
≤3 4-6 ≥7
Home is Rented > Amount of the Rent :…
Owned by the household

A.4 Identity of the Interviewee – Karta nu Varnan
Household Head
Yes
No > Relationship to Household Head :…
Gender M F
Age <30 30-45 46-60 >60
Duration of Residence under this roof
<1 year 1-5 years 6-10 years >10 years Native place

A.5 Education of the household's Head – Karta ni Bhartan
Illitarate Some schooling X-XII Class College

A.6 Occupation of the household's Head – Karta nu Kam
Service / Employee Professional (Doctor, Engineer, etc.)
Small entrepreneur Others > Specify :…

A.7 Monthly Household Income – Ghar ni Aavak
≤Rs.2000 >2000-4000 >4000 ≤6000 >6000-10000 >10000

B. Existing water supply – Nal nu Pani

B.1 Sources of water – Pani ni Vyavastha
Own connection > Number of connection(s) :…
Underground Tank (RWHS)
Shared connection
Neighbour connection
Other :…

B.2 Description of the Water supply system – Pani ni Vigato
Do you use the Tanki ?
Yes > Since how long ?…
> Storage capacity ?…
> How long do you keep the Tap open daily ?…
No > Why ?…
Do you keep the Tap open all through the day ?
Yes
No
Do you use the Bucket ?
Yes > How many Litres per Bucket ?…
> How many Bucket do you fill daily ?…
No > Why ?…
Do you use Overhead Tank ?
Yes > Since how long ?…
No > Why ?…
Do you use the water pump ?
Yes > How long daily ?…
No > Why ?…

B.3 Daily Requirement of Water – Pani no rojni Vaprash
Daily Use :
* In Summer : > In Litres :… > in Buckets :…
* In Winter : > In Litres :… > in Buckets :…
Do you use Different Sources of water for Different Purposes ?
Yes
No
Source of water & use for each of these purposes :

Purpose	Use	Source of water
Drinking / Cooling	>	
Washing Utensils	>	
Bathing	>	
Washing Clothes	>	
Cleaning the House	>	
Other > Specify :…	>	
Total	=	

B.4 User Satisfaction – Pani ni vyavastha kem lage chhe ?
Daily Time access to water :…
Are these hours convenient ?
Yes
No > Substitute hours ?…
Would you like hours of supply to be Expended ?
Yes > How many Hours ?…
> When ?…
No

Water Pressure : Low Normal High
Water Quality :
- Colour : Colourless Traces Other :…
- Odour : Odourless With odour
- Taste : Normal Salty Bitter Other :…
- Impurities : Without Floatg.part. Sediment

Have you ever experienced water born Diseases (ex.Cholera) in your household ?
Yes > Opinion about the water from the Tank :…
No

B.5 Fetching water from outside – Pani Bahaar ti Laavvu
Necessity to Fetch water from Outside home ?
Yes > When ? Everyday Summer Shortage
> How Often ? Occasional use Regular use Extensive use
> From which Source(s) ? Neighbours Other :…
> Daily Quantity of water fetched : > In Buckets :… > In Litres :…
> Number of Trips : > Daily :… > Weekly :…
> Person Fetching Water : Wife Children Housband All Others :…
No

B.6 Fulfilment of Water Need & User's Wishes – Pani Jarooriyat & Vaaparnar Icchha
Do you get Enough water for your need ?
Yes
No
What are you wishes for the improvement of the water supply ?
- Quality :…
- Quantity :…
- Pressure :…
- Other :…

B.7 Cost of Water & Willingness to Pay – Pani no Bhaav & Bharva ni Icchha
Monthly Cost of water :…
Are you willing to pay for water, provided a better service ?
Yes > How much/Litre ?…
> For which use ?…
No > Why ?…

C. Roof water harvesting system (RWHS) – Tanka nu Pani

C.1 Existence of RWHS – Tanka ni Vyavastha
<u>Functioning RWHS</u>
Existing since when ?…
Functioning since how long ?…
Frequency of use : Not using Occasional use Regular use Extensive use
<u>Non-Functioning RWHS</u>
Existing since when ?
Why abandoned ?…
Non-Functioning Since how long ?…
<u>Not having RWHS</u>
Interest for having that system ?
Yes > Why ?…
No > Why ?…

C.2 Description of RWHS – Tanka ni Vigato
<u>Functioning RWHS</u> <u>Non-Functioning RWHS</u>
Material used for :
- Walls :…
- Floor :…
- Ceiling :…
- Sealing ot Tank :…
Mode of Fetching water :…
Storage capacity (litres) :…
Roof Surface (s q. metres) :…

C.3 Consumption of water from RWHS
<u>Functioning RWHS</u>
Quantity of Tank water consumed & frequency of fetching water :

Purpose	Quantity fetched	Frequency of fetching
Drinking / Cooling	>	
Washing Utensils	>	
Bathing	>	
Washing Clothes	>	
Cleaning the House	>	
Other > Specify :…	>	
Total	=	

C.4 Opinion about RWHS – Tanka ni Vyavastha kém lagé chhé ?
<u>Functioning RWHs</u> <u>Non-Functioning RWHS</u>
Utility :…
Maintenance :…
Water Quality :
- Colour : Clear Traces Other :…
- Odour : Odourless With odour
- Taste : Normal Salty Bitter Other :…
- Impurities : Without Floatg.part. Sediment. Other :…

C.5 Utilisation of RWHS – Tanka no vaprash

<u>Functioning RWHS</u> <u>Non-Functioning RWHS</u>

After how many Rainfalls do you fill water in the Tank ?…
Do you use the system according to the principles of Astrology ?…
Yes > How ?…
No > Why ?…
Do you use the Tank according to any Traditional Practices ?
Yes > Which ?…
No

C.6 Filtration and purification of water – Pani ni Saar-sambhal

<u>Functioning RWHS</u> <u>Non-Functioning RWHS</u>

Before the water enters the Tanka > Do you Filter it ?
Yes > Why ?…
> How ?…
No > Why ?…
Once the water is inside the tanka > Do you Purify it ?
Yes > Why ?…
> How ?…
No > Why ?…
After having Fetched the water > Do you Purify water ?
Yes > Why ?…
> How ?…
No > Why ?…

C.7 Maintenance of RWHS – Tanka ni Saar-sambhal

<u>Functioning RWHS</u> <u>Non-Functioning RWHS</u>

Do you Clean the Tank ?
Yes > Is there a Time ?…
> How is it done ?
> Frequency :…
> Person in charge of the Maintenance :…
> Time required for Cleaning :…
> Cost & Person bearing the cost :…
No > Why ?…

C.8 Willingness to use RWHS – Tanka vaparva ni Icchha

<u>Non-Functioning RWHS</u> <u>Not-Having RWHS</u>

What are your wishes to improve the RWHS ?
……………………………………………………………………………………………………

<u>Non-Functioning RWHS</u> <u>Not Having RWHS</u>

Are you willing to Use the system ?
Yes > For which Purpose ? Drinking Utensils Bath Clothes House Other :…
No > Why ?…

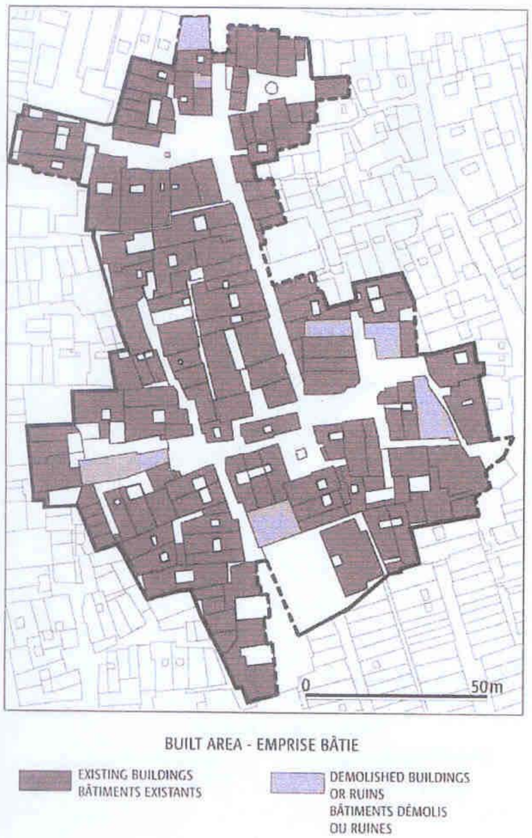
C.9 Financing the rehabilitation of RWHS

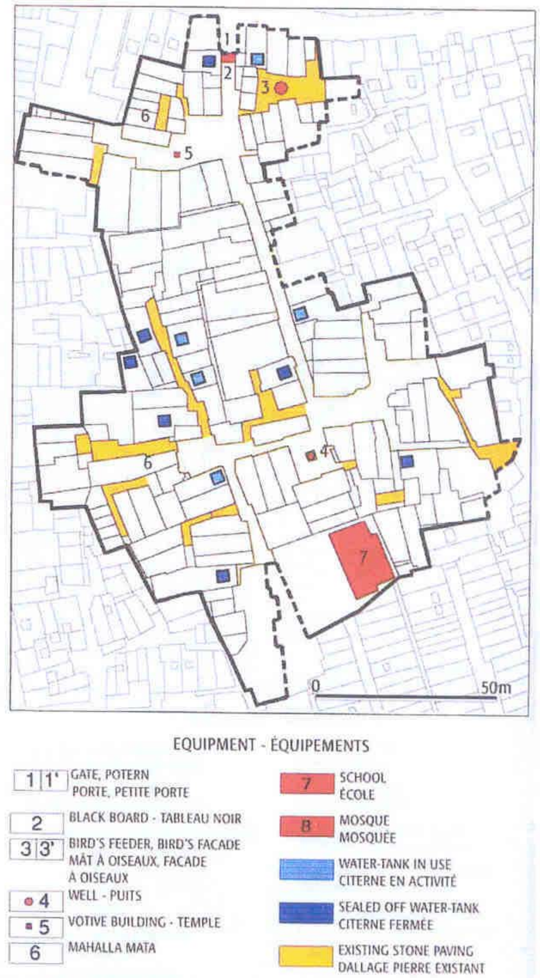
<u>Non-Functioning RWHS</u> <u>Not Having RWHS</u>

Would you like to have the system functioning/system to be built ?
Yes > Idea of the Cost :…
No > Why ?…
Would you be willing to pay the cost ?…
Yes
No > Up to How much would you be willing to pay the cost ?…
Would you be interested in Sharing the cost through a Financial Scheme ?
Yes
No

Annexure D

ANNEXE V *Carte 5* – **Localisation des *pols* enquêtés dans la vieille ville (*Pol* d'Akasheth)**





Annexure E

Carte 5 – Localisation des _pols_ enquêtés dans la vieille ville (_Pol_ de Jadha Baghat)