EERC

ENVIRONMENTAL ECONOMICS RESEARCH COMMITTEE

Theme: Water Institutions and Sustainable Use
EERC Working Paper Series: WIS-1

Reviving a Water Heritage: Economic and Environmental Performances of Traditional Water Harvesting Systems in Western India

Keshab Das

Gujarat Institute of Development Research, Ahmedabad

MOEF IGIDR WORLD BANK

Reviving A Water Heritage: Economic and Environmental Performance of Traditional Water Harvesting Systems in Western India

Submitted to the
Environmental Economics Research Committee (EERC)
under the World Bank aided
Environmental Management and Capacity Building (EMCaB) Project of the
Ministry of Environment and Forests, Government of India

Keshab Das
(Principal Investigator)

Supported by
Pritee Sharma
Ganibhai Memon

Gujarat Institute of Development Research
Ahmedabad 380 060

November 2002

Acknowledgements

Several individuals and organisations, both at government and non-government levels, have contributed in a variety of ways to initiate, conduct and complete this study on the vital theme of revival of traditional water harvesting systems in the arid regions of western India. We are thankful to the Environmental Management and Capacity Building Project, through which the Ministry of Environment and Forests, Government of India has sponsored this research. We are earnestly grateful to the subject experts and members of the Environmental Economics Research Committee and fellow researcher-participants at the various concerned workshops held for their guidance, comments and encouragement throughout the study. Special mention may be made of Jyoti Parikh, Paul Appasamy, K.K Narang, Maria Saleth, Robin Mukherjee, Kirit Parikh and Sudarshan Iyengar for their pragmatic and meaningful interventions.

We thank the following individuals, working for a better environment always, for their help and suggestions at different stages of the work. They are: Anupam Mishra, Prabhakar Sharma, Nafisa Barot, Aditya Lunavat, Sunil Chaturvedi, Sunita Narain, Raghuram Tata, G.S. Haripriya, Vinish Kathuria, Vivek Rawal, Sanjiv Virmanai, Sushma Iyengar, Binoy Acharya, Alice Morris, Bharat Bhati, M.L. Choudhary, Binja Ram, Dalpatbhai and Pemparam Barupal. At the initial stages of preparing the research proposal and subsequent discussions, the contribution of Dinesh Kumar is gratefully acknowledged.

0In the selection of sites, conducting the field surveys (both hydrological and socio-economic) and collection of secondary information from the various government departments and specialised institutions we have received much help from a number of generous individuals. We would particularly thank D.D. Sharma, Deepak Pachliya, G.P. Joshi, Deepti Sharma, D.D. Gupta, D.M. Bhandarkar, V.M. Sikka, Bhuvnesh Mathur, Bhanwarlal Jhathol, Jaiprakash Gupta, Sujit Sarkar, A.K. Jain, N.C. Ayachit and M.K. Badole. Engineering and hydrological consultancy provided by N.A Ansari, Y.S. Patel and Atul Merh was timely and useful. For their cooperation and hospitality we sincerely thank all the villagers of the selected sites.

Our special thanks to Sudarshan Iyengar, our Director, for his valuable comments, constant support and useful advice. For useful tips and friendly support we thank B.L. Kumar, Amita Shah and Tara Nair.

We sincerely appreciate the efforts of Jignasu Yagnik and Bharat Adhvaryu for data analysis and Jairam Desai and Jasubhai Makwana for data collection. For word processing support we thank Vasanthi V.A. and Sheela Devadas. We are thankful to Dixit Parmar for efficient photocopying and binding. We record our appreciation for the library staff and the administrative staff for their timely support.

November 2002

Keshab Das

Pritee Sharma

Ganibhai Memon

Contents

List of Tables

List of Maps

List of Figures

List of Photographs

EXECUTIVE SUMMARY

The impending crisis of scarcity of potable water, even in high rainfall zones, has been emerging as an issue of serious concern, nationwide. That it is no longer feasible to meet all the domestic water needs through perpetual and excessive withdrawal of groundwater is fairly well established by now. In India, whereas mechanisms to ensure prevention of overexploitation of groundwater by variety of competing users (including agriculturists, industrial units and urban settlers) continues to remain in the arena of policy debate, alternative ways and means to meet the growing demand for potable water from the rural sector have come under urgent consideration. This is particularly so as the state-run piped water schemes have left much to be desired in terms of reliability, adequacy and sustainability of supply in rural India.

The relatively recent reorientation in rural water supply, as part of the overall sector reform initiatives, emphasising user financing and local management has also been facing a number of constraints. The most notable of these hurdles concerns the inadequate or no recovery from the very poor rural households. Despite the soundness of the 'efficiency' argument, payment for capital expenditure by individual households in poverty remains a complex issue to tackle.

With this backdrop, the present study focuses on the potential of revival and modernisation of traditional water harvesting systems and addresses the vital problematique of ensuring sustainable availability of potable water in rural households through exploring alternative means. It is important to recognise that much of the 'enthusiasm' generated by the decade-and-a-half-old resurgence of interest in TWHS as remarkable alternatives in solving rural water crisis, needs to be validated against their actual potential. This is important as TWHS, by collecting and storing surface run-off and rainwater, represent excellent options in *not* drawing upon the valuable groundwater available beyond the rechargeable limit.

While TWHS are highlighted as the embodiment of evolved techniques based upon knowledge about local environmental and socio-cultural specificities, a large number of them can no longer cater to the total demand for water in the given village whose population kept growing. Further, barring a few, in many cases the traditional form of

community-based management of the structures has been a matter of the past. Gross neglect of these CPRs can be evidenced through the existence of damaged structures, polluting the water and even forcible possession by vested interests for private purposes.

Despite the indifference meted out to these age-old structures in many regions, especially when attention centred around the solution that was expected to come about through the modern piped water system, TWHS continue to function in numerous villages of India and if not fully, these sources fulfil demand for water for domestic use partially, particularly during the summer months.

In view of the rather limited and sketchy literature available on TWHS (meant mainly for drinking water purpose) and the growing need to appreciate their environmental and economic performance this study concentrated on three distinct TWHS as extensively found in the Thar Desert and Central Highlands Regions. The systems studied are bavdis in western Madhya Pradesh, wells in western Rajasthan and talavs in Kutch region of Gujarat. Subsequent to the selection of systems was the identification of sites in these regions, which would substantially represent the systems. Preliminary survey covering altogether 52 structures, comprising of 30 bavdis in Barwani and Khargone districts, 12 village wells, besides many other TWHS like bavdis and nadis, in Barmer and Jodhpur districts and 10 village talavs in Kutch district, was carried out. In general, most of the bavdis, which were recognised as CPRs, were either lying defunct or were used for irrigation for very short periods after monsoon. Some bavdis which were privately owned were relatively better maintained and in use. Across the villages in Rajasthan's study districts, the village wells in many cases were still the sole sources of drinking water, whereas in other villages the wells had gone dry or become saline. Talavs in Kutch like other TWHS have meted with negligence from communities, but unlike bavdis the talavs were generally reported to have been in use in most villages; although their usage has been reduced to livestock drinking and domestic purposes other than human drinking.

Three distinct approaches were followed:

Hydrogeological and engineering surveys were undertaken to understand the functional dynamics of the systems. These also included exploring possible technical interventions and modifications needed to improve the existing structures so as to enhance the availability of water. Estimates of cost of revival/ modernisation of TWHS were arrived at following these surveys and consultation with locally informed people, NGOs and concerned engineers and hydrologists in the local state/ taluka department offices. Similarly, estimates of capital expenditure and O&M for installing piped water network in the village, so as to provide tap connection to every household, were also prepared.

In order, to elicit information on demographic, socio-economic variables of the inhabitants and availability of infrastructural facilities, village and household level surveys were conducted. Special care was taken to obtain as much detailed data as possible on water related issues, such as, sources, pattern of use, time taken and distance covered to fetch water and perception about quality. The household and village level structured surveys were supplemented by fairly well attended focus group discussions, oriented in a manner to understand diverse views as expressed freely by the participants. The FGDs dealt primarily with the ticklish issues of community ownership and management of the existing TWHS.

The third but vital approach followed in the analysis related to the valuation of popular willingness to pay for provision of facilities of water through improved TWHS and supplying water through household level tap connections. These exercises in ascertaining households WTP from possible water supply devices, proposed through the creation of a hypothetical market scenario, provided the most interesting clues regarding popular perception about the essentially of TWHS and/ or modern piped water supply and their readiness to pay for either or both of these systems. The perusal of a slightly modified CVM, essentially by introducing options of mode of payment, was to settle for the most realistic amount that a specific household was ready to spare.

Drawing upon available documentation on TWHS and extensive field surveys in the broad ecological zones of Thar Desert and Central Highlands, it is obvious that TWHS not only vary substantially in terms of technology and management, but also their functioning depends so crucially on local discrete environment. Keeping these local specificities in view the potential of selected systems in terms of long-term sustainability can be described in brief, as follows:

Bavdis in South Western Madhya Pradesh: These exist in huge numbers. But, due mainly to their typically small size and limited storage capacity, these are not probably the best options for meeting community water needs. However, as observed by the hydrogeologists and water engineers, it is possible to deepen existing talavs and dig new ones, which in turn would recharge bavdis. In Dhababavdi (Barwani district) the currently functioning two bavdis serve limited purpose and, clearly, shall not be able to address the water scarcity problem of the entire village.

Wells in Western Rajasthan: Wells as TWHS in the western parts of Rajasthan have continued to prove useful even during summer months in the driest geoclimatic region of India. Unlike bavdis, wells are extensively used by the rural communities and are well maintained. All the wells visited in this region during the peak summer season, had good supply of water and the local perception about its quality was positive. An important hydrogeological characteristic of these wells surveyed was that the structures had been linked to underground perennial streams/channels. Also, these wells had been built with reference to the surrounding nadis (TWHS by themselves) so as to receive water recharged through them. Such ingenious selection of location and construction of the structures ensured a steady supply of water in the wells. These wells hold much potential to be revived and modernized. One most effective approach shall be to desilt, deepen and widen the concerned nadis; this will ensure a substantial increase in availability of water in the wells which may be stored for a long period of time. These structures are also viable options in these regions where piped water system is most likely to fail due to very low level of groundwater tables and in the absence of any perennial large surface water body like a river.

Talavs in Kutch, Gujarat: Almost all parts of the Kutch region have suffered substantial groundwater depletion and salinity impress. High incidence of poor groundwater bearing formations has resulted in severe water crisis in the region. Talavs certainly remain an important solution to the water problem in Kutch. In many villages visited, villagers considered water from local talavs to be of good quality and that water is available in these during prolonged spells of summer. The structures in the surveyed villages are unique examples of interconnected talavs, specially designed to prevent drinking water mingling with water in other talavs meant for washing or bathing purposes. In terms of size and capacity talavs are of large dimensions. These are in dire need of revival and modernization and can surely prove valuable in addressing the water shortage problem in Kutch region. Unlike the saline groundwater, talavs retain potable water and also recharge surrounding aquifers as also other TWHS like wells.

A commonly held observation disfavouring TWHS as potential sources of potable water concerns the ‘unprotected’ and ‘unsafe’ nature of the water. This important dimension of quality of water of TWHS must be taken into consideration in evaluating their potential. Water samples from the surveyed TWHS were collected for chemical analyses. In order to establish the bacteria present bacteriological analyses of the water samples collected were carried out in the laboratory following scientific instructions.

Irrespective of the fact that most villagers use the water of TWHS for drinking, cooking and other domestic purposes, the scientific tests indicate deficiencies in water quality. In most cases, as in the surveyed TWHS, quality of water can be upgraded substantially through cost-effective methods of treatment. Whether, some sources are to be abandoned, primarily due to lack of any scope to improve water quality, even up to the level of being used for domestic purposes (other than human drinking) only, should be left exclusively to the discretion of the scientific experts.

Whereas hydrogeological and structural engineering studies could work out interventions that would revive/ modernise the specific TWHS on a long-term sustainability basis, the estimation of both the capital cost as well as O&M indicates the financial investment that would be required. Such estimates are likely to represent the total use value of the environmental ‘commodity’ in question. As the analysis concentrates on potable water meant for domestic consumption only, the existence value of the commodity becomes irrelevant. Also, the nature of benefits of having access to good quality water is very much within the knowledge of the potential users. It may, hence, be held that the assessment of WTP undertaken in the study falls within the broad purview of the cost-benefit analysis. Assuming that the entire cost of revival/ modernisation would be shared between all the households in the village, an assessment of the willingness to pay for the improvised structures was made. The household surveys were based upon structured questionnaires prepared in the CVM framework. The introduction of the option of mode of payment was supposed to help reveal respondents' actual ability to pay for the amenities. A similar exercise in WTP was also conducted for laying a network of piped water system to provide household level tap connections.

The most redeeming aspect of the WTP exercise was that a substantial 65 per cent of all households surveyed responded in the negative (that is they were *not* willing to pay any amount whatsoever) for either or both the hypothetically proposed facilities. Despite having a series of independent variables, indicating the most likely socio-economic factors, regressed with the amount of WTP, the state level results showed only per capita consumption of water (PCHUMQ) in Madhya Pradesh and Rajasthan and caste of the household (CASTE) in Gujarat as the significant variables affecting the WTP. However, when similar regressions were run for Rajasthan none of the variables was found to be significant.

In fact, a close examination of the nature and extent of households' WTP provides interesting insights into such a pattern of response. First, most households in the Rajasthan villages are living in extreme poverty and, naturally, have refused to pay at all for the water from either TWHS or piped systems (Table 1). The villagers are perfectly aware that the existing wells, from where they have been drawing water free even during the peak summer months, shall continue to meet their minimum basic demand for potable water. However, if extreme poverty could lead to negative response for paying for water, in Dhababavdi (the MP village) quite a few villagers living below poverty line have expressed their willingness to pay even small sums for water facilities. This is so, as this village has practically exhausted all existing sources and the value for water has clearly risen for them.

Table 1: Willingness to Pay Across Sample Villages

(Percentages)

Particulars	Madhya Pradesh		Rajasthan		Gujarat	
	Dhababavdi	Temla	Nagana	Godavas	Tera	Reha Mota
WTP_{TWHS}	26.8	11.8	14.3	4.7	77.3	11.8
WTP_{PIPE}	22.0	9.8	5.7	-	18.2	7.8
$WTP_{O\&MTWHS}$	39.0	76.5	97.1	100.0	93.2	90.2

$WTP_{O\&MPIPE}$	29.3	13.7	17.1	-	72.7	13.7
$WTP_{LABOURTWHS}$	92.7	84.3	97.1	100.0	77.3	74.5

Second, very unlike the capital cost, most villagers in all the surveyed villages were willing to pay for the O&M for TWHS; in many cases the estimated contribution for O&M for the proposed piped system was much higher than that for TWHS. People's willingness to contribute labour free indicates the preference for the revival/ modernisation of the TWHS. An important aspect of this exercise in assessing WTP is that even the most sophisticated methods of valuation may be inadequate to elicit information on the WTP behaviour if the respondents refuse to participate in the 'bidding' process due mainly to abject poverty and rejecting the very proposal that potable water could be priced for the rural poor.

A number of technological options to revive/ modernise the TWHS have been put forth by the hydrogeological and engineering experts. Most of the considered suggestions have been highly discrete (specific to the system or site *per se*) and often have incorporated ideas from local inhabitants. For instance, as may be seen from Table 2, especially the bavdis may not prove to be adequate sources of water due to their small size. Table 2 presents brief notes on suggested technological interventions which may serve as useful guidelines in appreciating the utility and sustainability of individual systems.

Through village level focus group discussions (FGDs) as also structured household level surveys issues of management and maintenance of TWHS have been dealt with. Table 3 presents some relevant aspects. In case of the well in Nagana in Rajasthan and the talav in Tera in Gujarat management and maintenance of the TWHS were done by the local community. These are the villages where the use of water from TWHS has been extensive and also the quality of water has been well maintained. In the remaining cases, a preference has been expressed for complete or partial involvement of state government in managing and maintaining the sources. In these villages, the general lack of confidence in the efficacy of the sarpanchs in managing these sources is striking. The possibility of public and private participation in financing the revival of the TWHS in these villages may be explored.

It was apparent that TWHS were not or will not be able to cater to the *total* requirement of drinking water in the villages, mainly due to the rise in population in the past decades. Nevertheless, if revived/ repaired and, importantly, the ownership is shifted from the present private to its original community based, these sources can be of substantive use, especially, during summer.

Table 2: Structural Issues Relating to the Revival of TWHS

Bavdi		Well		Talav	
Dhababavdi	Temla	Nagana	Godavas	Tera	Reha Mota
Receding water table	Receding water levels	Depleting groundwater levels	Depleting water levels Salinity increases with depleting water levels	Groundwater is reported to be saline	
	Poor accessibility	Poor accessibility	Poor accessibility	Poor accessibility	Poor accessibility
Structure is small		Groundwater is becoming saline		Huge capacity and favourable topography	
Unsuitable for human drinking	Water unsuitable for human drinking			Only sweet water source as groundwater has become saline	Reported to be unsuitable for drinking but good for cooking
Desilting of catchments would improve water table	Desilting of local talav is essential for recharge of the bavdi	Desilting of local talav would improve the water and reduce salinity		Some people reported to have had diseases because of the bacterial contamination of the water during late summers	Desilting would improve the groundwater level in the area

Piped water system, though preferable, has implications of increasing cost in future either due to increase in population or depletion of groundwater. Additionally, the ubiquitous problem of unreliability of piped water supply has serious implications for considering alternative sources.

Hydrogeology specific technological strategies to harness rainwater and modernise TWHS need to be explored as enhanced supply *per se* can reduce costs significantly. In such ventures whether and how state can intervene or shall seek private participation, both for financing and providing technical and management support is an issue to be explored. In TWHS, the trickier issue is management with community participation. The control over the system by the local dominant group is difficult to wish away.

Interestingly, the large-scale prevalence of TWHS in its varied forms in the three states has not been adequately documented in the rather limited literature available on the subject. Locating the TWHS through the field survey *in itself* was an important aspect of the study.

Table 3: Management Issues in Revival and Maintenance of the TWHS

Bavdi		Well		Talav	
Dhababavdi	Temla	Nagana	Godavas	Tera	Reha Mota
Presently privately owned, Government should take over and manage	Government/ Panchayat managed; Distrust among the people regarding the usage of funds	Panchayat managed	Improper local management	Community managed	Government should take up the management
Sarpanch is illiterate: Lack of leadership	Lack of Leadership, Sarpanch illiterate	Leadership is caste biased		The local leaders are highly motivated and concerned for the water management	
No participation from women	Women participated but reported being ignored	Women do not have a say in the local management	Lack of sense of responsibility for maintenance of the existing structures	People are united for maintenance of the system	Generally people were not interested in taking up the maintenance and management of their water supply.

Chapter 1

Context, Scope and Objectives

1.1 Introduction

The scarcity of potable water as a formidable problem encountering most parts of India has come to be recognized as an issue of serious concern, especially during the last two decades or so. Availability of safe and fresh water in adequate quantity, it has been realized, can contribute substantially towards enhancing livelihood options as also the quality of life itself. The problem has assumed acute proportion in the arid and semi-arid zones, often eluding a lasting and workable solution. At the heart of the crisis lies the fast depletion of groundwater resource, which, evidently, accounts for about 80-90 per cent of total water used for domestic purposes. The excessive and growing pressure on groundwater can easily be attributed to a series of *human-made* factors including unmindful exploitation of groundwater by rich farmers engaged in water-intensive commercial agriculture and the growing demand for the resource from the vast urban population for whom piped water supply pumped through the deep tubewells is practically the only available source. Moreover, rapid industrialisation, particularly in the western and southern states, has been exerting growing pressure on water.

Apart from the decline in actual availability of water, there exist umpteen instances of polluting/contaminating both surface and groundwater bodies by irresponsible human action. As polluted or unsafe water is unusable for drinking and other domestic purposes, there occurs huge wastage of water, which could have been made available otherwise. Some of the instances of this nature include polluting water bodies by allowing mingling of untreated industrial and agricultural waste, including toxic substances (as in pesticides), letting domestic solid and liquid waste contaminate household/ community water sources (such as stand posts, wells and ponds). These environmentally most undesirable acts of unconcern have been emerging as major constraints on the sustainability of fresh water supply in the rural areas[1].

[1] In the environmental health sphere, it has been observed that diseases caused due to polluted/ unsafe water have been responsible for the death of over 1.5 million children (below five years of age) annually in rural

Drinking water being an indispensable and basic ingredient for survival and health, the state has never missed an opportunity to emphasize the need to cover the entire population with safe water supply. The declared policy commitment to this effect can be traced from the very First Five Year Plan document onwards. That such a goal has not been actualized despite investments in varied projects has also been admitted unequivocally by the government. A typical drawback in most state-run water supply schemes has been identified as lack of coordination between various departments, which are 'partly' responsible for the supply and maintenance of the sources. This dysfunctionality, naturally, has resulted in unreliable and inadequate supply and wastage of the resource. The added disadvantage has been non-involvement of the local consumers in the location, usage, operation and maintenance of the sources; this has led to inefficient use and unscientific management of the scarce resource. It has been observed that the lack of realisation and acceptance of the notion of water as an economic commodity (and not a *free* good to be provided copiously by the government), especially by most rural population has rendered the proposition of ensuring sustainable supply of water to all the villages practically impossible.

Contrary to the aforesaid supply side approach to the water scarcity problem, or, rather, deriving a lesson from the same, the focus has shifted to what is known as the demand-driven approach to provision of water. This relatively recent turn-around in emphases and policy promoting private participation in water supply mainly follows the sector reform measures initiated over two decades back with the launching of the International Drinking Water Supply and Sanitation Decade in 1980. A key element in this 'novel' approach has been pricing of water, wherein payment of user charges is supposed to ensure efficiency in both distribution and use. So far as rural Indian users are concerned, many consider payment for potable water is an impractical proposition.

Based on a strict 'quality'-driven definition of 'public safe' water source, the government estimates of FC, PC and NC habitations indicate the enormity and severity of water

---

India. Moreover, yearly loss of over 200 million person days of work has also been linked to poor quality of water.

crisis in rural regions[2]. As reported in the Ninth Plan document, by April 1997, a staggering 61724 habitations were designated as NC, 3.78 lakh as PC and 1.5 lakh habitations were identified as villages with serious water quality problems, such as presence of excess fluoride, nitrate, arsenic and salinity in the water bodies. Accordingly, an estimated over 90 million rural dwellers in India do not have access to safe drinking water sources.

Two important points need to be noted here: first, the official definition of public safe source (and the FC, PC and NC classification of sources based thereupon), in fact, often, is both unrealistic and inadequate. For one thing, the FC, PC and NC status of a given source can vary significantly between rounds of survey; the deterioration of status from FC to PC to NC or even FC to NC is a commonly observed phenomenon. For the other, the source being defined as public and safe, both privately owned and open access 'unprotected' sources remain outside the purview of coverage[3].

In fact, as may be noted from Table 1.1, private and the so-called 'unprotected' sources continue to be used by about one third of rural households for drinking purposes. As aptly observed by Raj (1996: 3), "Water available from a well within the household premises – which is, in fact, the main source in most rural areas – must also be regarded as safe… In some states like Assam, Orissa and Kerala, the inclusion of water available from wells within the premises makes a significant difference; the percentage of rural households with access to safe drinking water rises then from about 43 to nearly 61 per cent in Assam, from a little over 35 to nearly 47 per cent in Orissa and from as low as 12 to 71 per cent in Kerala. These are areas with heavy rainfall and

---

[2] In operational terms, a habitation to be qualified as 'fully covered' (FC) by a public safe source would imply the existence of at least one stand port or hand pump for a population of 250, the maximum distance between the source and habitation being 1.6 km. in plain areas or 100 meters in hilly tracts. The source should be supplying at least 40 lpcd, or else, it would be classified as 'partially covered' (PC) or 'not covered' (NC), as the case may be.

[3] "… a habitation in Kerala or Assam having several private wells or hand pumps and *no* public source would be recorded as NC, whereas a habitation in the semi-arid Saurashtra or western Orissa region with only one public source (even *ad hoc* arrangements like supplying water through tankers) providing less than 40 lpcd of water, but no private sources, would be classified PC (or FC, if the source provides above 40 lpcd of water, as per the norms)" (Das, 2001:272).

where it is customary for rural households to have wells within their premises". Hence, non-inclusion of a variety of potable water sources, which may not be officially classified as 'safe', precludes options of technological and institutional interventions to improvise the same. Similarly, omission of habitations without a single public safe source, from the official NC list has also been noticed in a validation survey of NC habitations in Gujarat (Das and Kumar, 1998: 4). It has been held that the national norm of 40 lpcd as the standard measure can be misleading. This may vary substantially across geo-climatic regions as also socio-cultural practices.[4]

Table 1.1.1: Principal Sources of Drinking Water in Rural Households

Source	Households (%)		
	1988 (44th Round)	1993 (49th Round)	1998 (54th Round)
Tap	15.5	18.9	18.7
Tubewell, Handpump	39.1	44.5	50.1
Well	39.1	31.7	25.8
Tank/Pond (only for drinking)	2.2	2.1	1.9
River/Canal/Lake	2.4	1.7	1.3
Spring	1.4	0.9	1.7
Other	0.6	0.3	0.4
All	100.0	100.0	100.0

Source: *Sarvekshana*, XXIII (3), 82nd Issue (Special), Jan-March, 2000, p. 55. As reported in Mehta and Menon (2001: 130)

The second major point is that, in the government sphere, the entire supply of water for domestic use in rural households depends almost exclusively upon tapping groundwater bodies. With marginal sum allotted towards recharge of groundwater, as through deepening and desilting of water structures like talavs, the pressure on groundwater has gone up considerably in many parts of the country. The government water supply paraphernalia (including the Accelerated Rural Water Supply Programme and many regional schemes) covers the whole gamut of water supply through piped system.

4 Interestingly, with the aim to ensure drinking water supply to all the rural habitations, the central government has recently relaxed the norms. The new 'liberal' norms approved by the Union Cabinet "envisage provision of 55 litres per capita per day…as against 40 litres per capita per day at present". Further, "the norms for distance of source have also been relaxed to within half a km in the plains and 50

Installing handpumps, stand posts, providing households with tap connections and distributing water through tankers (at least in some arid regions, particularly during the dry months) are various manifestations of this 'obsession' with the modern piped water system at the government level. Even though an estimated over Rs. 35000 crore has been spent on piped water supply schemes by both state and central governments since the inception of Planning in India, numerous rural habitations do not have access to adequate good quality water.

It needs to be noted that so long as the piped water supply, irrespective of whether the supply-driven or demand-driven approach is followed, continues to be largely based on groundwater, it essentially proves to be an environmentally *unsustainable* strategy. The fast depletion of groundwater due to massive extraction must be compensated for by adequate efforts at recharging the sub-soil and aquifers. This is essential in arid (or, semi-arid) tracts as also those areas receiving much rainfall but with excessive run-off. Apart from being environmentally unwise, overuse of groundwater (without proper replenishment) only shall result in dwindling of the resource. This reduction in supply can, in fact, lead to its price rise. Hence, it can be argued that in the dual interest of the sustainability of the resource as also ensuring low levels of user charges, the vital effort should aim at enhancing the availability of water. It follows, automatically, that the cost of water (if may be charged to the user) can only be fixed following all possible steps towards ensuring an increase in the natural availability of water in a given region.

1.1.1 The Context: Reemergence of Interest in Traditional Water Harvesting Systems

With growing instances of failures of government-sponsored modern piped water systems, at least in terms of unreliable timing and quantity of supply, poor maintenance and high costs, a number of alternative mechanisms of water collection, storage and management have been tried out, often by para-statal bodies, including local

---

metre elevation in the hills". 'Norms for Village Water Supply Diluted', *The Times of India*, Ahmedabad Edition, June 26, 2002, p. 7.

communities in certain places. A particularly strong engagement has been with what may broadly be called the traditional water harvesting systems (TWHS). As the name suggests, these systems (the very many varieties of them, discussed in Section II of this Chapter) have been in use for centuries and, essentially, been based on tapping surface (monsoon run-off of rivers or streams) and/ or rainwater. Apart from being hailed as 'great' techniques devised in consonance with the local environment (including, hydrology and topography) and socio-cultural specificities, these systems helped recharging groundwater, fulfilled local demand for the resource and, above all, could be sustained for great length of time.

The reemergence of interest in the TWHS has, *inter alia*, certainly been prompted by the falling groundwater tables in most regions due to overexploitation, contamination as also failure of regular monsoons. Remarkable instances of potential of these structures in collecting and storing huge quantities of potable water in such arid and rain-starved regions as Rajasthan, Kutch and Saurashtra regions of Gujarat, south western Madhya Pradesh and arid tracts of south India have come to be documented widely during the last decade-and-a-half (For instance, see, Agarwal and Narain, 1997; Vaidyanathan, 2001; Agarwal, Narain and Khurana, 2001; Bhagyalakshami, 2001; Reddy, Barah and Sudhakar, 1992; Vohra, 2001 and Barah, 1996). Impressed with the performance potential and ingenuity of TWHS, some protagonists have even gone to the extent of placing their entire faith on these, convinced that the modern piped water systems are a waste of resources and lack sustainable, people-oriented technological back-up.

Despite the enthusiasm and hope generated by the TWHS, a few serious limitations are associated with these. A particularly disturbing aspect is that most of these systems have either fallen to disuse either due to structural deficiencies or human neglect. Wherever these systems are in a functional state, most of these are no longer able to cater to the growing demand of the rising population of the locality. In fact, in a large number of cases, the water is no longer used for drinking or cooking purposes, as the water has become unclean or contaminated.

Although there exists a fairly good number of writings on the TWHS, including those in vernacular languages, hardly any analytical insights could be obtained therefrom. Most of these provide interesting *descriptive* details of the structures, anecdotal information on their history and aspects of management. A striking limitation of most of such available 'accounts' on TWHS is that a dispassionate assessment of their present and potential techno-economic utility is found missing. As TWHS are being seriously reconsidered as possible solutions to the ever-growing crisis of drinking water, it is important to go beyond 'glorifying' the historical roots of these systems. In fact, there exist a few studies analyzing the techno-economic feasibility of TWHS, mainly used for irrigation purposes (Vaidyanathan, 2001). A close perusal of the literature on TWHS revealed the paucity of studies analyzing the techno-economic issues of TWHS, used mainly for fulfilling drinking water needs. It was realised that in the absence of an objective evaluation of the potential of variety of TWHS, mere holding positive or negative opinion about them does not help benefiting from these traditional systems embodying indigenous knowledge and a clear social purpose. This study is an attempt to address the aforesaid missing dimension of the available literature and also to enquire into the issues of revival and modernization, through technological and institutional interventions.

1.1.2 Scope and Objectives

The present study aims to examine economic and environmental performance of TWHS in Thar Desert and Central Highlands regions of India covering the states of Gujarat, Rajasthan and Madhya Pradesh (Map 1.1.1). In these dry regions water harvesting is deeply rooted in the social fabric itself. Like many parts of the country, the tradition of community based systems of water collection and supply is many centuries old; in these regions numerous traditional water harvesting structures exist even today in different parts of these states. The local communities had developed many efficient, sustainable and unique systems of water harvesting, which not only suited the local physiography and the climate, but also were consistent with the socio-economic and cultural characteristics of the localities. However, not all these systems in these regions, as, in fact, elsewhere in the country, are in functional state. Accounts of TWHS are replete with instances of structural damages, collapse of community management, inadequacy of the system to meet the burgeoning demand of the local population and severe decline in the quality of water from these sources. These instances however do not preclude possibilities of revival, modernization and use of TWHS as important sources of water for domestic use. The vital issue is to explore such possibilities through systematic techno-economic enquiries. A first major step towards this objective, we need to understand the physical, socio-economic and institutional processes that led to their degradation. Also, these systems are required to be evaluated for their technical feasibility, economic viability and environmental soundness in order to be considered as an option in water management decision-making.

Keeping in view the aforesaid scope the central concern of the study is two-fold:

(i) to analyze, in a comparative framework, the potential contribution of TWHS in the Thar Desert and Central Uplands regions in addressing water management issues through detailed hydrogeological and engineering assessment of the selected systems.

(ii) to enquire into the socio-economic and institutional factors influencing the revival, modernization and use of selected TWHS as also appraising the preference for the modern piped water system.

The specific objectives are as follows:

(i) to analyze the nature of sustainability of the selected TWHS and constraints faced in achieving it, by taking recourse to hydro-geological and engineering approaches. This would also provide a reasonable idea about the costs of revival, modernization and maintenance of the selected TWHS and cost of involved in installation of alternative modern piped system.

(ii) To enquire into the households' willingness and ability to pay for revival of TWHS and getting individual tap connection to their homes.

(iii) To examine factors influencing pattern of consumption of water at the household level.

(iv) Results of chemical and bacteriological analyses towards establishing the status of quality of water from the sample sources.

1.2 Traditional Water Harvesting Systems in Western India

Different types of water harvesting systems exist in the arid and semi arid regions of India. These TWHS were primarily meant for a) crop irrigation/ land improvement and b) drinking, domestic and religious uses. The major components of the TWHS comprised: (i) *stream flow* (diversion dam)- canals, weirs, bhandaras, etc.; (ii) *storage structures and rainwater harvesting*- tanks, talavs, bavdis, eris, ahars, tankas, nadis, khadins, johads, etc.; (iii) *distribution systems*- kavalais, pynes, guhls, kuhls, lakes, channels; and (iv) *Groundwater sources*- wells, dug-wells, kuis, kunds, etc.

In Table 1.2.1 a broad typology of different TWHS as found in India is presented; these relate to diverse ecological regions. A detailed description of the TWHS prevalent in the Thar and Central Uplands regions, are given in Table 1.2.2.

Table 1.2.1: Typology of Indian Traditional Water Harvesting Systems

Ecological Regions	Systems for domestic water
Hill and mountain regions	a) Natural springs were often harvested. b) Rainwater harvesting from rooftops. c) In the Northeast, spring water is often carried over long distances with the help of bamboo pipes.
Arid and semi-arid regions	a) Groundwater harvesting structures like wells and step wells were built to tap groundwater aquifers (eg. *bavdis* of Rajasthan). b) Groundwater harvesting structures like wells and step wells were invariably built wherever they were possible, especially below storage structures like tanks to collect clean seepage for use as drinking water (eg. several such structures can be found in the forts of Chittor and Ranthambore). c) Rainwater harvesting from roof tops (eg. *tankas* of Pali). d) Rainwater harvesting using artificially created catchments, which drain water into an artificial well just about any land, can be used to create such a

	water harvesting structure (eg. *kunds* of Rajasthan). e) Special rainwater harvesting structures which help to keep sweet rainwater from mixing with saline groundwater and, thus, providing a layer of potable water (eg. *virdas* of Kutch). f) Horizontal wells similar to the *qanats* of the middle east to harvest seepage down hill slopes (eg. *surangams* of Kerela).
Plains and Flood plains	Dugwells
Coastal Areas	Dugwells

Source: Agarwal and Narain, 1997: 27

Table 1.2.2 Traditional Water Harvesting Systems in the Thar and Central Highlands Regions of India

Description	Geographical regions	Remarks
Tanks		
Constructed *in situ* with massive masonry walls on four sides and almost impermeable floor as a standard pattern. They are either square or rectangular and had an enormous water- holding capacity. Tanks were invariably provided with an efficient system of canals to bring rainwater from the catchment areas and are thus constructed downstream.	Tanks are common all over India, and most parts of the Thar region have tanks as the systems for rainwater harvesting. The prominent ones are: Jodhsagar, Navlakha (Bundi), Jaisamand (Udaipur), Kolayat, Gajner, Gangasarovar (Barmer), Gadisar, Govindsagar, Gulabsagar, Malka, Mooltala, Sudhasar (Jaisalmer). Jodhpur district has 35 tanks. In the towns around Bikaner there were many tanks. The catchments of these were quite extensive. E.g.: Kolayat: 14,900ha, Gajner: 12,950 ha, and Gangasarovar: 7,950 ha. There are many community tanks in Phalodi (Jodhpur): Ranisar, Ramsar, Hiwasar, Siwsar, Nyatalah, Khatri and Chiklin. All over the Thar region of Gujarat Tanks are the most commonly occurring rainwater harvesting systems. The very famous tanks of Kutch are: Hamirsar and Desalsar in Bhuj, Sidhsar in Anjar, Narayan Sarovar in Lakhpat, Mansarovar in Palanpur, Ranmal in Jamnagar. The Central Highland region also has many tanks, some of which are Udaipur alone: Jaisamand, Udaisagar, Rajsamand, Fatehsagar, Pichhola etc. In Banda (U.P), there were a large number of tanks throughout the district. There are four tanks in Jhansi: Barwasagar, Kachnah, Mogarwara and Pachwara. Tanks and embankments were common means for storage of rainwater in the district of Mirzapur, Varanasi, extending from Ganga to East Satpura hills. There are several old tanks in the region neighbouring	Tanks in Thar were built for both drinking, and irrigation purposes. But now most of these are now polluted, their catchments encroached in urban areas. Today most of the tanks in Thar are facing extinction. Tanks in Udaipur are all heavily polluted and with raw sewage opening into it, due to the large effluent disposals from Cement, fertilizers, pesticides, distilleries and mineral based industries. The four tanks of Jhansi are used by the irrigation division. Tanks and embankments were used for both consumption and irrigation, but now very few are in use and only for irrigation. Some of the old tanks in Damoh are still functioning but others need desilting and renovation. Sanchi tanks are silt laden, now taken p for renovation by the Japanese government and EPCO, an MP Government organization.

	Damoh. There are three ancient tanks on the Sanchi hill.	
Talavs or Talabs		
A *talab* is a popular word used locally for water reservoirs situated in valleys and natural depressions. In old *talabs*, only the slope side was provided with strong parapet walls to hold the rainwater. Other sides were naturally supported by outcrops of hillocks or elevated rocky formations.	Jodhpur has 40 talabs as reported, eight in the city in the hilly terrain, 300-350 years old. The oldest is Ranisar. Most of the talabs are located over Chonka-Daijar plateau at varying heights and depths.	These talabs have been the main source of water for the human and animal population until recently. Water from these talabs is still used for drinking and other purposes by the local population. But their catchments are being eroded and destroyed at many places by urban activities. They are also feeding a large number of wells and *baoris*. If the *talabs* go dry, the survival of a large number of wells and *baoris* will be threatened.
Nadis		
Are the village ponds used for storing water from an adjoining natural catchment during the rainy season. A nadi is essentially a natural surface depression, which receives rainwater from one or more directions. Some nadis have stonewalls on one or two sides to enhance capacity of water retention. Water availability of a nadi would range from two months to a year. Nadis in dune areas varied in depth from 1.5-4.0 m and were characterized by heavy seepage losses, smaller catchments and lower runoff. Nadis in sandy plains were deeper (3-12m) had large catchments, lower seepage and water	Most of the villages in the Thar have their own nadis. In Barmer, Nagaur, Jaisalmer,; 1,436; 592 and 1,822 nadis were found. Each village in the district (Jodhpur) had one or more nadis. SDS survey found 25 nadis in and around Jodhpur. Eg. Range-ki-nadi and Pritaro-nadi (450 years old).	Heavy sedimentation, high evaporation and seepage losses are factors affecting nadis. Poor maintenance and improper utilization of these systems has also resulted in heavy pollution and presence of guinea worms, water hyacinth mosses & algae in many places and many nadis have become silt laden play grounds and waste disposal grounds.

availability upto 7-10 months.		
Wells		
Well is a shaft sunk into the ground to obtain water/ a water spring or fountain. In Rajasthan the depth of wells varied from 76-122 m, and one well was reported to be as deep as 150m.	Common village wells exist all over Rajasthan Bikaner: Traditionally many houses had wells. In old records, some 125 open wells have been listed in different parts of Jodhpur. The oldest ones being Jetha Bera and Chopasani Bera. Their ages however varies from 120-530 years. Traditionally, wells have been the principal means of water harvesting in Gujarat. In Kathiawar, water is found close to the surface and wells are numerous. In the Central Highlands region also there are many wells: like in the Udaipur town there are numerous bavdis below the Pichhola and Fatehsagar. Wells were common across the central uplands tract of Uttar Pradesh covering the districts of Jalaun, Banda, Hamirpur, Jhansi.	Wells were the most important source of water in all of Rajasthan and were used both for irrigation and drinking water purposes. Of the 98 wells surveyed in Jodhpur, 74 are still in use and 23 have been abandoned and one has been lost. Among the operational wells, 53 are used for drinking water and 13 for irrigation and cattle drinking. The 24 wells, which have been abandoned or closed, either have no water or have polluted water. However, 23 old wells are still being used by the PHED to maintain the city's water supply. About 2-3 % of the city's population still uses well water for drinking. Wells are the only source of drinking water in Damoh region of MP.
Canals		
Canal system consists of numerous watercourses, channels and aqueducts to carry rainwater to city's various nadis and talabs.	Canals were the most commonly found systems originating from tanks. Canals were used for irrigation. Major canals in Jodhpur City are Chota Abu, Kaliberi, Keru and Nadelao, Mandore-Fedusar canal and several small canals culminate in one canal, the Hathi canal, which is about 6 m deep. Umedsagar lake is fed by Umedsagar canal.	Canals were used for irrigation. These canals have been mutilated over the years due to mining activities in the catchment area and are blocked by rubble.

Tankas		
Are the systems of rainwater harvesting from rooftops. Rainwater that falls on the sloping roofs of houses is taken through a pipe into an underground tanka built in the main house or the courtyard. The first spell of rain would not be collected, as this would clean the roof and the pipes. The water from the tankas was used only for drinking purposes.	Each house in Bikaner had traditionally built tankas, which were used for drinking water purposes. Tankas were constructed in Balotra in Barmer district and Phalodi in Jodhpur district.	Out of the 40,000 houses in Phalodi there are about 2000 houses, which maintain their tankas.
Bavdis		
Bavdis or the community step wells are shallower than wells, they have beautiful arches along their full height. Bavdis can hold water for a long time because of almost negligible water evaporation when compared to other water bodies. Step wells were used for various reasons, and their location often suggested the way in which they would be used. When a step well was located within or at the edge of a village, it was mainly utilitarian purposes and as a cool place for social gatherings, usually for drinking purposes for traders, military and travelers.	The Chonka-Daijar plateau is an important physical feature of this region. The slopes vary considerably but are very precipitous at some places. The whole plateau serves as the water catchment functional surface water bodies (like nadis, talabs, tanks and lakes) and indirectly for about 154 groundwater bodies like wells and baories and jhalaras. Bheru bavdi, Chand bavdi, Jagu bavdi, Idgah bavdi etc. The SDS surveyed 45 bavdis in Jodhpur: 16 inside the city and 29 outside the city. Step wells are found all over Gujarat but more so in the northern and central parts. In Kutch only a few step wells are found and they are small and without elaborate carving. Many step wells are found on the routes from Patan in the north to the seacoast of Saurashtra. There are numerous bavdis below Udaisagar and Fateh sagar in Udaipur.	In Jodhpur district about 30 bavdis still hold water, 20 have potable water. The condition of half of the baories is fairly good while the remaining half need immediate care. By tradition bavdi water is not used for drinking. The PHED is exploiting the water of 11 bavdis for the city's water supply, which suggests they have excellent water holding capacity. Bavdis in Udaipur were the only source of drinking water earlier but now these are no more used for drinking water. Twenty five bavdis in Udaipur have been revived after the 1987-88 drought and are now used by the PHED for supplying water though the pipeline.

Jhalaras		
Jhalaras were essentially meant for community bathing and religious rites. Often rectangular in design, jhalaras have steps on three or four sides. The basic functioning is like that of a bavdi.	The SDS was able to locate 2 jhalaras inside the Jodhpur city and 6 outside, 7 of which still hold water, but none is being used for drinking purposes. The oldest jhalaras are the Mahamandir jhalara, Kriya-ka-jhalara, and Mandore jhalara.	PHED is making use of the two jhalaras for water supply and the Nolakha jhalara is being used for irrigation.
Lakes		
	Jodhpur has 5 large reservoirs viz. Balsamand, Lalsagar, Kailana, Takhatsagar, and Umedsagar lake located in the south west of the city.	These lakes can hold about 700 million cubic feet of water at a given time which can support about 0.8 million people for 8 months. But now a days, even during normal rain years, these lakes do not get adequate water because of the poor state of catchments and canals which carry rainwater to them.
Toba		
Technically similar to nadi is the toba, another traditional technique for harvesting rainwater in arid areas. Toba is the local name given to a ground depression with a natural catchment area. A hard plot of land with low porosity, consisting of a depression and a natural catchment area was selected for the construction of tobas. In addition to providing water for human and livestock consumption, the grass growing around the tobas provides pastures for grazing livestock.	Each village of cattle breeders had 5-6 tobas, depending on caste and community composition. Tobas in desert region of Thar are commonly found in Bikaner district.	Tobas are seasonal sources of water and are not used for human drinking. Tobas are available roughly for 4-5 months.

Kunds		
In the sandier tracts, the villagers of the Thar Desert had evolved an indigenous system of rainwater harvesting known as kunds or kundis. Kund, the local name given to a covered underground tank, was developed primarily for tackling drinking water problems. Usually constructed with local materials or cement, kunds were more prevalent in the western arid regions of Rajasthan and in areas where the limited groundwater available is moderate to highly saline. The kund consists of a saucer- shaped catchment area with a gentle slope towards the centre where a tank is situated. Openings or inlets for water to go into the tank are usually guarded by a wire mesh to prevent the entry of floating debris, birds and reptiles. The top is usually covered with a lid from where water can be drawn out with a bucket. Kunds are by and large circular in shape , with little variation between the depth and diameter which ranges from 3-3.5 m. The catchment size of the kund varies from about 20 sq. km to 2 ha depending on the runoff needed and the availability of spare land.	Kunds were more commonly found systems in Barmer and Churu districts. Jalwali, a village on the road from Bikaner to Anupgarh has nearly 300 kunds. Each household in this area owns 4-5 kunds. There are numerous kunds in Gujarat also, though their number is less than Rajasthan. Kunds were usually found in Northeastern Gujarat.	Kunds in Rajasthan were built for drinking water purposes. In Gujarat construction of kunds was for agricultural purposes. Some kunds were even used as tanks for tanning of leather or dyeing of clothes. The catchments of most of the kunds have been destroyed. Some of the kunds are still functional, and the water from the piped supply (Rajasthan canal) is stored in these kunds.

Kui and Dakeriyan		
Kuis also known as beris, were dug next to tanks in order to collect their seepage. Beris are normally 10-12 m deep and were entirely kutcha structures. The opening would generally be covered with planks of woods. These are the shallow wells dug in harvested fields where rainwater is impounded for kharif cultivation. Dakeriyans are well-like structures which harvest seepage water of the kuis.	Kuis can still be found in abundance in Lunkaransar tehsil, of Bikaner. Villages falling between Mohan garh and Ramgarh in Jaisalmer district and also on the tract between Phalodi and Diyatra (Jodhpur district).	Dakeriyans were meant for drinking water purposes.
Khadin		
The khadin system is based on principle of harvesting rainwater on farmland and subsequent use of this water-saturated land for crop production. A khadin is an earthen embankment built across the general slope, which conserves the maximum possible rainwater runoff within the agricultural field. It is usually 1.5-3.5 m high and made on three sides of the lower contours of a farmland with one side left open for rainwater to drain in from the surrounding catchment area. The length of the embankment varies from about 100-300 m depending on the site. The embankment not only helps to increase moisture in the submerged land and prevent monsoon runoff, it also prevents washing away of the topsoil and the manure added to	The whole network of khadins exists in district Jaisalmer and Jodhpur.	

it.		
Virdas		
In dry riverbeds and lakes, scoop holes are known as virdas in Gujarat. The water in the virdas is usually sweet, being located in the top layers of the sand.	In Banni area of Kutch, and at the edges of Rann	
Haveli System		
The system comprises holding rainwater in the embanked fields, which are enclosed on four sides, and retaining the water so impounded until the sowing time approaches. After this no watering is needed for the crops.	The farmers in the upper part of Narmada covering Jabalpur, Narsighpur, part of Damoh and Sagar in M.P. have been practicing water harvesting and run off farming technique called "Haveli System". The system is prevalent in Jabalpur, Narsinghpur, Hoshangabad and parts of Damoh and Sagar districts covering an area more than 0.14 mha (million hectares).	Today more than 50% of the Haveli system has been destroyed because of the changing cropping pattern. The bunds are broken and the water is not allowed to stand in the fields.
Jali Karanj and Bhandaras		
Bhandaras or Storage tanks which collect groundwater from underground springs flowing down from the Satpura hills towards the Tapti river. The water is carried through subterranean conduits with a number of connected wells to a collection chamber called jali karanj, and from there to the town. The water from jail karanj in mughal times would reach Burhanpur through clay pipes, which were later replaced with iron pipes. At every 20 meter along the entire path of the tunnel from source (bhandaras) to jail karanj air shafts have been provided.	System specifically designed by Mughals based on gravity.	Today people living around these airshafts use them like wells, as water flows through the tunnels throughout the year. The system is still useful but due to sheer negligence may soon become history. The main problems are over the years; pores and openings have got blocked due to the accumulation of the deposits of chemicals, declining groundwater levels, sedimentation of shafts and tunnels.

Pat System		
The sys tem is such that it takes the advantage of the peculiarities of the terrain to divert water from swift-flowing hill streams into irrigation channels called pats. Pat system is diversion from the stream by putting a small bund (embankment) across it.	The Bhils of Jhabua district of M.P. devised this system of rainwater capturing.	The area under pat irrigation is increasing every year.

Source: Compiled from Agarwal and Narain, 1997

Chapter 2

Methodology and Approaches

2.1 Finalising Locations, Systems and Survey Instruments

The empirical core of this study derives from extensive, primary surveys and focus group discussions at the household levels. Two distinct approaches have been deployed to elicit and analyse field level information. The first relates to development of case studies. Details of steps followed in arriving at the systems and sites finally selected to be studied as individual cases have been provided in the first part. This essentially involved visiting a number of locations (shortlisted from the informed sources) and deciding on the appropriate ones. Further relevant survey instruments used for development of case study method have been listed in this section. The second part briefly discusses the second approach namely the Contingent Valuation Method (CVM) and the modifications attempted at in conducting the surveys to ascertain the Willingness to Pay (WTP).

Apart from the socio-economic surveys, relevant hydrogeological and engineering enquiries are also envisaged as an integral component of the study. For one thing, in order to arrive at the estimates of cost of revival of the specific TWHS and that of identifying and tapping groundwater resources for the laying of pipelines, the hydrogeological and structural engineering surveys were essential. For the other, hydrogeological data gathered through field trips (and supplemented by secondary information) were useful in establishing the potential sustainability of the individual systems.

The entire survey exercise was conducted in two rounds. The first round involved

(i) finalising the sample sites and the systems;

(ii) collecting basic village level information including sources of water

(iii) household survey focussing on socio-economic characteristics and pattern of water use

(iv) Focus Group Discussions to obtain villagers views and perceptions about specific system related issues.

In the second round:

(i) geohydrological information was collected, structural features were noted and chemical and bacteriological testing of the water samples and

(ii) cost estimation for the revival of TWHS and installation of the piped system was followed by the household survey exercise for willingness to pay for the same

2.1.1 Selection of Systems and Sites

It needs to be emphasised that this study deals with such two distinct geo-climatic zones, namely Central Highlands and Thar Desert, which are designated as the driest belts of India. The severity of drinking water problem is, probably, one of the most serious in these areas. Although, much of the available literature describes TWHS with reference to their utility as sources of water for irrigation, this study is confined to systems meant for drinking and domestic purposes only. In the selection process special care has been taken to ensure that the systems, covered are a) primarily (if not exclusively) being used or were being used in the past for drinking and domestic purposes; and b) are still in a functional state, irrespective of whether currently these are being used as sources of drinking or domestic water.

Following literature survey and intensive discussions with different stakeholders, including villagers and concerned government and NGO officials, three distinct systems, widely prevalent in these regions, were selected from the existing ones, such as talavs, bavdis, wells, kuis, nadis, tankas, kunds, canals and lakes. The systems chosen were: bavdis in southwest Madhya Pradesh, wells in west Rajasthan and talavs in Kutch region of Gujarat. Details of the survey locations and systems have been given in Table 2.1.1.

The Phase I survey focusing on the three different systems was conducted in six villages. The details have been provided in the following.

Table 2.1.1: Locations and TWHS Chosen for Field Survey

State	District (Village)	Geo-Physical Region	TWHS
Madhya Pradesh	Barwani (Dhababavdi) Khargone (Temla)	Central Highlands	Bavdis
Rajasthan	Barmer (Nagana) Jodhpur (Godavas)	Thar Desert	Wells
Gujarat	Kutch (Tera and Reha Mota)	Thar Desert	Talavs

Madhya Pradesh

Detailed references were collected from representatives of local NGOs (namely, Bhujal Samvardhan Abhiyan, Vibhavari and Samaj Pragati Sahyog in Dewas); Office of the District Collector and Chief Executive Officer, Dewas; Deputy Director, Narmada Valley Corporation, Barwani; Deputy Collector, Khargone; senior school teacher, Khargone; sarpanchs of the villages covered, and local residents. Based on discussions with the above individuals and in keeping with the information from the literature reviews, it was observed that of the many TWHS like the wells, bhandaras, bavdis, havelis and talabs, bavdis were the most widespread system of water harvesting in the entire western region of Madhya Pradesh. Bavdis are commonly used for drinking. Given the predominance of this traditional system of water harvesting in Khargone and the newly formed Barwani districts of Central Highlands region of Madhya Pradesh, these two districts were chosen for the detailed survey.

Barwani District

According to the information gathered through primary sources, there are more than 70 bavdis in Barwani District. In Table 2.1.2 brief notes on villages visited before finalizing the site and the system have been presented.

Table 2.1.2: Villages/ TWHS Visited: Barwani District

Description of villages/ bavdis visited, but not surveyed in detail	Number of Bavdis
Barwani Town: These bavdis are: Moti Mata bavdi, Champa bavdi, four bavdis in Devi Singh's Garden, Jhamaria Wali bavdi, Jhalabavdi and Hathi Dan bavdi. Originally, these were constructed as sources of drinking water, However, later, after coming of the Narmada pipe water supply and digging of wells and hand pumps, water from these bavdis were used for irrigation and construction works (Plate XM.3.S).	9
Chakeri and Mandwada: On the way to Thikri-Anjarh Road, about 35 km from Barwani, these bavdis are not used as drinking water source now; these are	2

mainly used for irrigating nearby farms for a few months after the monsoon.	
Tamdi Bavdi: Situated few kilometres away from Dhababavdi, this bavdi is also used only for irrigation in the post-monsoon period or livestock drinking purposes, for the rest of the year lies defunct (Plate XM.4.S).	1
Lal Bai Phul Bai Mata Bavdi: Located on Jilwania road near Segaon, this large bavdi is practically owned and controlled by the local temple. Limited public access and religious bias in its operation and management were noted.	1
Rajpur Bavdi: The one, which is located closer to the town, is still used by some as a drinking water source and the other, half-a-kilometre away from the village, is mainly used for irrigation purpose (Plate XM.2.S).	2

The village chosen for detailed field survey was Dhababavdi, situated 11 km from Barwani, on Shilavat Road. The location was interesting partly due to the existence of four bavdis in one village, of which two were still functioning. Although all these bavdis were supposed to have been built during the old times as drinking water facilities for travellers in this dry area, the current uses of the functioning ones are no longer for the same purpose.

Dargah ki Bavdi, the functional one located on the road head was reported to be more than 300 years old, built during the Moghul period. The then maharaja of Barwani took interest in encouraging villagers to keep the bavdi clean; before every monsoon, this bavdi was properly desilted. Until the last 35 years this bavdi was the sole source of drinking water for all villagers, but now the bavdi is in control of a local influential Patel household. They have installed an electric motor in the bavdi and have been using water for irrigating their farms. The bavdi is connected with a pipeline and water is drawn both in the morning and evening for about two hours. This bavdi is linked to a natural spring at the bottom and during the summer the water comes in slowly and within hours the bavdi gets full with water again.

Khargone District

Discussions revealed that there are many bavdis in the district and, particularly, some prominent ones in the Khargone town and its vicinity. With the passage of time water from the latter ones have been used for different purposes, such as, irrigation, house construction, hotels, etc., that is, other than their initial use as popular drinking water sources. Apart from the three working bavdis, there were many bavdis in the town, which have now been part of the Municipal Corporation as the catchment areas of these bavdis have been converted into housing construction sites. Further, even houses have been built over a few bavdis. Information on a few villages with bavdis visited in the district as part of finalising survey location is given in Table 2.1.3.

The selected village, Temla, has a huge bavdi more than 300 years old. This bavdi has been so designed and located that it used to supply drinking water for all the households in the village and also for the cattle until the last 5-6 years. The intricate structure of the bavdi includes different platforms meant for collection of drinking water, washing and other domestic uses, and also for drinking by the cattle. With the introduction of public hand pumps during the last 8-10 years, this bavdi has been gradually abandoned. Moreover, as it was felt that the bavdi water was not safe for drinking, the villagers stopped using the system.

Five years ago the bavdi was deepened so as to locate any spring at the bottom, but in vain. Presently the bavdi is used as a temporary storage tank. A tube well about 3 km away from the village road head has been dug and water is transferred to the bavdi from there. From here water is transferred to an overhead tank and is supplied to all the households. Due to the low pressure of water during the summer months it is easier to store water in the bavdi instead of directly pumping it into the overhead tank. Almost all the households in the village are connected with modern piped system. The co-existence of both the modern piped water supply system and the traditional system of bavdi, prompted us to select this village for the household survey and focus group discussion.

Table 2.1.3: Villages/ TWHS Visited: Khargone District

Description of villages/ bavdis visited, but not surveyed in detail	Number of Bavdis
Khargone Town: These bavdis are: Kali Mata bavdi, St. Jude School bavdi and Gopalpura bavdi. Special mention may only be made of the first one. The Kali Mata bavdi, large and elaborately ornate, is located at the Khargone main bus stand close to the Agra-Bombay Highway. Built by a trader in the British era, presently, this bavdi lies in the privately erected compound of a local businessman, who has cleaned the bavdi and decorated the structure with bulbs, only to use it as an ice cream parlour. This bavdi, closely resembling vavs in Gujarat, is a two-storied structure above the ground and is 16 metres deep, with a natural spring at the base. It, now, serves as a source of water to his restaurant. A 7hp electric motor has been fitted in the bavdi and it is able to supply water throughout the year.	3
Nandgaon: This village is about 30 km from the Oon town. Kasar Bavdi, the biggest of the three, is over 200 years old and presently is under the control of a local	3

farmer. The other two bavdis are small, dry and not in use for several years.	
Gauri Dham Bavdi: Located on the outskirts of the city and is also owned by the same businessman who now owns the Kali Mata bavdi. The water from this bavdi is fetched for the construction of the colony nearby and also for irrigation of a large garden nearby (Plate XM.1.S).	1
Sailani Bavdi: This defunct bavdi is located 22 km from Khargone on Kasravad Road towards Indore.	1
Ojhara: These bavdis have been completely ignored after the coming of piped water supply in the village.	2

Rajasthan

There are different types of TWHS in Rajasthan: for example, tankas, talavs, jhalaras, kunds, kuis, wells and khadins. These systems are found according to the topography, soil structure and rainfall pattern. Rajasthan is divided into two distinct hydrogeologic zones, namely, Thar Desert and Central Highlands. The districts falling under the Thar region are Ganganagar, Bikaner, Jaisalmer, Churu, Jhunjhunu, Sikar, Nagaur, Jodhpur, Barmer, Jalore, Pali and Sirohi. The districts of Jodhpur and Barmer were selected for the present study purposes as the traditional water harvesting systems in these two districts have been gaining popularity due to recurring droughts in recent years. Moreover, consultations were held with the senior faculty at both the geography department of Jodhpur University and the Central Arid Zone Research Institute (CAZRI) in Jodhpur to confirm the wisdom in the choice of the study districts. NGOs such as Unnati at Ahmedabad and Jodhpur, Vasundhara Sewa Samiti at Kalyanpur at Barmer and Dalit Vikas Samiti, Manaklav in Jodhpur were also contacted for guidance to know about the prevailing situation of water supply systems in these districts.

Barmer District

In Barmer District, Kalyanpur Tehsil was selected purposively, as many traditional water-harvesting systems are found here. Some of them are very old, about 1000 years, some in good working condition and some have been forsaken for the modern systems like piped supply, bore-wells, hand-pumps, etc.

As stated earlier, according to the available literature tankas are supposed to be the most prevalent system in Barmer and Jodhpur. Hence, detailed enquiries were made about tankas. However, as it turned out through field visits, most of the tankas here had been constructed by the local NGOs and these were public access systems built only 4-5 years ago. The community tankas constructed in the Kalyanpur Tehsil were also surveyed. On the basis of discussion with the villagers it was found that the individual tankas in the households were very few over there because most of the people could not afford to construct tankas at a household level. Only 3-4 tankas were there in each village. The two important emphases (applicable to all the three states) adopted for this study were i) the systems should be locally predominant and ii) these should be accessed by the local population. Interestingly, the tankas did not meet the aforesaid requirement of the study. Instead in all the villages wells (big and small) were the most commonly used system other than the modern systems. But the piped water supply was not effective as the frequency of supply was very low; water flowed only twice or thrice a month. Also due to the very low level of groundwater, people depended only on rainwater as the source of drinking water. These drinking water sources are nadis, tankas and wells. Brief details about villages visited for studying the water harvesting systems are given in Table 2.1.4.

Table 2.1.4: Villages/ TWHS Visited: Barmer District

Description of villages/ wells visited, but not surveyed in detail	Number of Wells
Sitli Gaon: An old and dry well exists here. During the rainy and winter seasons water is found here and at times this water is used for domestic purposes only and not drinking (Plate XR.1.S). A small kui near the well collects the seepage water. Near the village there is a talab with five bavdis in it, but at present all of them are dry (Plate XR.5.S). The water is supplied to the village through a pipeline from Kalyanpur.	1
Charlai Kalan: A small village with 15 households, it has piped water supply pumped from a well at Nevah. A small kund is also there but is dry for last three years because of very low rainfall.	1
Nevari Gaon: Water is supplied through pipeline from Kalyanpur. But since this water supply is irregular and insufficient, the NGO from Kalyanpur has constructed a community tanka four years ago. Although there is nadi near the village, now it has been practically rendered defunct by years of silt deposits. Water remains there only for a few days (Plate XR.3.S).	1
Bankiavas Kalan: In this village a 500 year old well is found. The villagers use this water for drinking through out the year excepting during the summers. The continuous drought for the last three years has failed to recharge the well nearby. Piped water supply from a nearby village is there but rarely works. People buy water from tankers from Kalyanpur and Jodhpur. Large-scale out-migration has taken place due to the drought condition in the region.	1
Mandali: Piped water is supplied in this village under the Rajiv Gandhi National Drinking Water Mission (RGNDWM). An overhead tank (GLR) has also been constructed, but there is limited supply of water, as the motor does not function properly. Tube wells have also been dug but the water is saline. A community tanka to store the rainwater has been built by the local NGO.	1

Nagana was selected for the purpose of household survey, as the system is very old, still under use and supplies water to whole of the village. A huge well, about 800-900 years old, is the only source of water supply in this village. A tank (GLR) and a motor, under the RGNDWM, have been installed here to pump water from the well. Although the water level recedes during the summers, since ages this well is supplying water for the whole of the village. The water from this well is exclusively used for drinking purposes as villagers realise that if this is used for irrigation it will go dry. In the past, camels and bullocks used to draw water through the pulley, but now it is done through the electric motor.

Jodhpur District

In Jodhpur District, Mandor and Bhopalgarh tehsils were surveyed as these areas were reported to have many wells and nadis. Table 2.1.5 provides information on the villages visited as part of selection of the village for detailed survey.

Table 2.1.5: Villages/ TWHS Visited: Jodhpur District

Description of villages/ wells visited, but not surveyed in detail	Number of Wells
Manaklav: There is a 500-year-old talav in the village, which has been the major source of drinking water until hand pumps and tube wells came in. Neglected all these years, only recently the local government has undertaken the cleaning (desilting) of the talav under the drought relief campaign.	
Pagbavdi: There exist a very old talav and two wells in the village. But now the water of these two wells has become saline. In the talav there are six bavdis, which were used by different communities to fetch drinking water. All of them are dry now.	2
Basni Lachhaa: There are two bavdis, one well and a 125-year-old talav in this village. For the last 12 years, with the coming of the piped water supply, the talav has become a source of livestock drinking only.	1
Thabukada: This village has many wells, but most of them are either dry or saline or have hard water. In the big talav here there are 112 small bavdis (Plate XR.4.S). Rainwater collected in these bavdis or the talav is used for drinking by the local communities.	Many
Dahikada: Though this village is connected to a piped water system, there is a well owned and used by a local Patel for irrigation purposes. Poor villagers use the water for drinking also (Plate XR.2.S).	1

The village selected for the household survey was Godavas, where a 600 year old well is still being used. Drinking water in this village is available mainly from the well and the pipeline. The piped water supply, however, is not regular. A tank constructed near the well is connected to the stand-posts. Whenever piped water is not available, water is pumped from the well and is supplied to the stand-posts. There are a few wells in the village but the water is saline, hence unusable.

Gujarat

There are many traditional systems of water harvesting in Kutch district like wells, vavs, canal, tanks, however, the most common system is the talavs. The district geographically falls in the Thar region and is known for its particular topography, physiographical features make an excellent site for the water harvesting system of talavs.

Kutch District

As per the proposal, we selected Kutch District for the study and the system selected for Gujarat study was talavs. Local NGOs such as Abhiyan Rahat Samiti at Bhuj; Sahjeevan; VRTI, Mandvi; ANARDE, Anjar; and officials at the Water Supply Sub-Division at Dayapar as also the key functionaries (sarpanch, talati, deputy sarpanch) of the villages surveyed were contacted to seek guidance on the selection of the sites for study purpose. Brief notes on areas covered under pilot survey have been given in Table 2.1.6.

One of the villages chosen for detailed survey was Tera in Abdasa Taluka; here villagers continue to use talavs for their various household purposes. Tera has three huge talavs reported to be as old as 300 years. The first is meant for washing and bathing, the second is for drinking purposes and the third for animals. In addition to these traditional systems of water supply the modern piped supply (Rassalia Water Supply Scheme) also exists in the village, although, here again, water supply is not reliable. This has increased villagers' dependence on the talavs for drinking water purpose at least.

The second village selected for survey was Reha Mota. There is one huge talav here, about 100 years old, which serves the water needs of the village round the year. There are a few talavs in the nearby villages also. The regular source of drinking water in this area is talavs but now due to the coming up of the government pipeline people have started neglecting the traditional systems. There are stand-posts, bore wells and taps, however, due to irregular electricity supply these modern systems do not work always. Tube wells are mostly with the richer people as they have installed motors on the source. Water overflowing from this talav goes to a second talav that is meant for other domestic uses.

Table 2.1.6: Villages/ Town/ TWHS Visited: Kutch District

Description of villages/ town/ talavs visited, but not surveyed in detail	Number of Talavs
Kayyari: Narayan Sarovar is one of the most well known talavs in Gujarat (Plate XG.4.S). With the installation of the desalination plant close to the Narayan Sarovar and also the renovation of the nearby Kanoj Dam (built during the British period), the village is well connected with the modern piped system of water supply. The water from the Sarovar is used exclusively for religious bathing purpose, but not for at all	1

for drinking. There are four stand-posts in the village.	
Bhuj: Two major talavs in this township are Hamirsar (Plate XG.5.S) and Desalsar, over 400 years old. The catchment of the talav is spoilt now as the new buildings have come up in the vicinity; these talavs are no longer used. The town receives water through the piped water supply system, every alternate day for 1-2 hours.	2
Vira: In this village in the Anjar Taluka, there are two talavs, which are about 150 year old -- the Rata Talav is for drinking water and the Upadhyay Talav for washing and bathing (Plate XG.2.S). There are four wells in the talavs (Plate XG.6.S), which are used for fetching water when the talav water recedes. Though there are 100 private wells in the village, most of them have saline water. The village is connected with a pipeline and has two stand-posts; but the pipe is broken and the water supply is irregular. Hence, water is supplied daily through tankers. For the last two years due to drought the talav is not being filled and the people are using only tanker water.	2
Anjar: Sidhsar talav in Anjar town, was traditional source of drinking water. The talav has become highly polluted and full of silt deposits now used only for livestock drinking and dumping of solid wastes from the town (Plate XG.1.S). Another small talav in the town has become victim to negligence due to urbanisation.	1
Wandai: A huge traditional in the village is well maintained by the temple trust. The talav has cemented steps on all the four sides (Plate XG.3.S).	1

2.1.2 Sampling of Households

The major emphasis in the selection of households was placed on the fact of their using the selected TWHS. Depending on the number of households using the TWHS in a given village, the proportion of sample households selected from each village varied. Factors such as topography, distance between the TWHS and the houses also influenced the sample size. Table 2.1.7 provides information on the sample size and the number of participants in the focus group discussions held in these villages. Details of the sampling procedures as adopted in the six different villages have been discussed as follows:

Table 2.1.7: Sample Size and FGD Participants in the Study Villages

Village	Number of households in the villages	Number of sample households surveyed	Number of participants in the Focus Group Discussion
Dhababavdi (Madhya Pradesh)	105	50	29
Temla (Madhya Pradesh)	608	57	27
Nagana (Rajasthan)	138	40	22
Godavas (Rajasthan)	200	67	13
Tera (Gujarat)	475	50	30
Reha Mota (Gujarat)	400	60	20

Dhababavdi (Barwani): The village Dhababavdi has hilly and undulating terrain. The total number of households in the village is 105. However, out of the total eight habitations, only those in the vicinity of the Dhababavdi were selected, as the remaining habitations never used these due to the distance factor. The three habitations near the bavdi thus chosen were Patel falia, Mankar Mallah falia and Ralji falia. All the 57 households in these three habitations were selected, but the effective number of households surveyed was 50, due to the existence of joint families. In the focus group discussion, of the 29 participants 25 were male and 4 female (Plate F.V1.1).

Temla (Khargone): The total number of households in Temla village is 608. A sample of 10 per cent of the total households was selected for the survey. Due to the non-availability of the members of the households the number of households finally surveyed was 57. For the focus group discussion, 27 villagers participated (Plate F.V2.1). No women joined the meeting.

Nagana (Barmer): According to the village records, obtained from the local primary school teacher, there are 138 families in the village, of which 38 were located in their farms. Of the remaining 100 families, 55 lived in a habitation near the well. All the households living near the well were selected as sample. However, during the survey it was found that many of these households had migrated to Jodhpur, Gujarat and nearby villages for stone crushing and other wage labour. Hence, only 40 households could be surveyed. The focus group discussion was conducted and 22 men participated in the discussion (Plate F.V3.1).

Godavas (Jodhpur): The total number of households in the village is 200 and 67 households selected, which lived in the habitation near the well, were selected. Only 43 households were surveyed, as the remaining household members had migrated to Jodhpur. Only 13 members of the village participated in the focus group discussion (Plate F.V4.1).

Tera (Kutch): There are 475 households in this village. As almost all the inhabitants were reported to be depending on the talavs for all their water needs a sample of 10 percent of the households was taken. Through random sampling technique in all 50 households were chosen for household survey. Thirty persons joined for the focus group discussion (Plate F.V5.1).

Reha Mota (Kutch): This village has total number of households as 400. Of the total households a sample of 60 households was surveyed, as these households were using water from talav for domestic purposes. In the focus group discussion 20 persons participated (F.V6.1).

2.1.3 Survey Instruments

For the purpose of collection of both quantitative and qualitative data from the primary source, elaborate survey instruments were prepared. The survey was carried out in two distinct phases. In Phase I the following survey instruments were applied:

1) *Village Level Questionnaire*: This had two parts. Part A was used to collect information on area, broad socio-economic characteristics of village population, access to public utilities and basic amenities. Part B was meant for eliciting detailed information on existence of traditional and modern sources of water supply, groundwater levels, irrigation sources, and other relevant water related issues.

2) *Household Level Questionnaire*: This survey schedule had been designed to canvass household level information on demographic profile of the family, social status, occupation, sources of Income, housing details, land holding and also variety of information on domestic water collection and use.

3) *Questions for the Focus Group Discussions* (FGDs): These questions based often on management, institutional, financial and local socio-political dynamics were essentially open ended in nature. These were used to facilitate uninhibited expression of views by the participants. Basically, the FGDs purported to deliberate on the issues concerning collective ownership and role of the community in sustaining the specific TWHS.

2.2 CVM and Assessment of WTP: A Note

Probably one of the most controversial yet extensively used approaches in environmental economics literature is the contingent valuation method (CVM). This method "involves the use of sample surveys (questionnaires) to elicit the willingness of respondents to pay for (generally) hypothetical projects or programs. The nature of the method refers to the fact that the values revealed by respondents are contingent upon the constructed or simulated market presented in the survey" (Portney, 1994: 3). As time and again, the reliability of such responses in reflecting the realistic values has been questioned, how the contingent value survey is conducted assumes significance in the final analysis.

There, however, is no standard set of procedures that may be used to design a contingent value survey. As observed by Hanemann (1994: 21), "While there is no panacea, various procedures have been developed in recent years that enhance the credibility of a survey and make it more likely to procure reliable results." These address a variety of dimensions including sampling, instrument development, formulating of the valuation scenario, questionnaire structure, and data analysis. These few basic aspects as discussed by Reddy in 1991, which, however, continue to form the essential core of such an exercise, have been assigned importance in the present study.

In the absence of any substantial study dealing with WTP for TWHS in the Indian context, it was important to devise a set of steps, which could be effectively used in the survey process. During the Phase I household survey, the respondents were explained about the potential of TWHS in enhancing the supply of water in the village. Although no 'bid' amount reflecting the household level contribution to the capital costs, in the event the structure was revived was suggested, nor even the exact nature of technological interventions that could be attempted was detailed, the respondents were asked a few questions indicative of their interest in the revival of the systems.

In Phase II of the survey, however, detailed field visits and geohydrological and engineering enquiries were undertaken to ascertain the most appropriate and cost-effective means to revive/ modernise the existing TWHS. Appropriate estimates of capital cost and maintenance expenditure were calculated using scientific parameters. Once such estimates were available, per household share was worked out from the same. It is this amount that was used for the household survey to elicit a realistic idea about the amount that a particular household was willing to pay for the proposed revival/ modernisation of the TWHS and the piped system. Details of the costs (both in terms of money and labour cost) estimated per household for the revival of TWHS and for installation of modern piped water supply system are presented in Table 2.1.8.

Needless to add that prior to canvassing the willingness to pay (WTP) questionnaire to the respondents, an intensive effort was made to explicate and make the respondent familiar with the household level cost of collection of water as construed in terms of time spent and distance covered in fetching water, health costs as a result of water related illness and costs due to irregular supply and scarcity. The nature of interventions specific to the revival of TWHS and laying of pipelines, including identification of a groundwater source, were also explained to the respondents. The direct and indirect benefits gained therewith from each type of intervention in both the short and long run were indicated with details, including saving of time and costs involved and the likely benefits from the same. Following this stage the respondent was asked if he/ she was aware that such an intervention could actually help to increase the availability of water in the village. Information regarding the perception of quality of water drawn from the concerned TWHS and modern piped water supply, wherever available, was also collected to assess the awareness of the respondent regarding the benefits of having not only adequate and regular supply of water but also of improved quality through the suggested interventions.

Table 2.1.8: Household Level Estimated Cost of Revival of TWHS and Laying of Piped System by Sample Village

Village	Cost of Reviving TWHS	O&M Costs of TWHS	Number of Human days Required	Cost of Laying Pipe System	O&M Costs of Piped Water Supply
Dhababavdi	8000	1000	120	1800	360
Temla	1000	200	90	500	300

Nagana	5000	10	60	3000	500
Godavas	6250	10	60	2600	500
Tera	3500	5	30	7500	100
Reha Mota	1400	5	60	400	150

Towards this revival/ modernisation, the question of whether the respondent would be ready to pay the 'bid' amount (fixed through the hydrological and engineering studies) was asked. Even when the initial answer was in the negative, the respondent was pursued to reconsider the proposal if a lower amount was what he/ she would be willing to pay. As a step further in this attempt to obtain a better understanding of the respondents' ability to pay, a set of options in easier mode of payment was envisaged. This rather innovative modification was tried out to judge the actual demand for a certain 'commodity'. In this manner, the valuation of an environmental good especially by very poor households can be comprehended. The entire exercise was repeated for the proposed laying of a piped network so as to provide household level tap connections.

The modified CVM applied in this study, for a 'commodity' whose total use value is most supposedly known to the respondents, may have projected a realistic picture of the nature and extent of WTP, mainly of the rural poor households. This is the use value, which arises out of both current use and future potential use. It may be noted that, the systems (i.e., TWHS) are often small in size and highly localised, hence, the scope for transforming these structures/ ambiences into spots of tourist interest is practically non-existent. Due mainly to this, it is not possible to undertake any environmental economic analysis of the selected systems by taking recourse to the techniques such as Travel Cost Method and Hedonic Pricing. Further, water from these sources is not used beyond the domestic sphere; for instance, TWHS serving irrigation needs elsewhere are not included in this study. As is well known in a typical Cost-Benefit Analysis of water for irrigation, variables such as crop productivity, vegetation coverage, local income generation need to be valued. However, in the present study the benefits of availability of adequate fresh water at the household level are well recognised; the external effects of good quality water supply are large and positive. So far as health benefits are concerned reduction of infant mortality rate (IMR), incidence of diarrhoea and a host of water related diseases, improved sanitation and hygienic practices are common. Further, whereas time saved in fetching water from long distances may be utilised for a variety of economically productive activities, increased water supply *per se* opens up the possibility of establishing a number of high value adding enterprises, particularly dairying. All these benefits, however certain they are, do not accrue in the short run.

The households interviewed in the first round for estimating the water consumption pattern were canvassed for the WTP exercise in the second round. The households were classified into two types namely, those with household tap connections and those without. The questions for obtaining responses concerning the WTP for the revival of TWHS and its future operation and maintenance and also nature of participation in the process were common to both the types of households. However, the schedule to elicit information on the WTP to pay for laying of pipelines and provision of household tap connection thereof, was canvassed only to the households without private tap connection. Nevertheless, the households with private taps were also asked for their willingness to pay for a better supply. Details of the number of households surveyed in the second round are given in Table 2.1.9.

Based on data collected through the two rounds of household survey, in all the three states, multiple regression analyses were carried out to establish the statistical relationship between domestic water use and selected socio-economic characteristics of the sample households. Also logistic regression analyses were done to determine the factors affecting households' willingness to pay for the revival of TWHS and for laying of modern piped water supply system.

Table 2.1.9: Category-wise Households Surveyed in Sample Villages

Village	Number of Households Surveyed			
	Round I	Round II		
	All	All	Without private tap	With private tap
Dhababavdi	50	41	41	-
Temla	57	51	12	39
Nagana	41	35	35	-
Godavas	43	43	43	-
Tera	50	44	44	-
Reha Mota	60	51	18	33
Total	301	265	193	72

Source: Field Survey

Note: Households surveyed in Round II are only those who were available and had been covered in Round I.

Multiple Regression with Per Capita Consumption of Water (CONWAT)

$$Y = a + \beta_1 X_1 + \beta_2 X_2 + ... + X_n \beta_n$$

where,

Dependent Variable:

CONWAT	Per capita consumption of water per day in litres

Independent Variables:

PCINC	Per capita monthly income
CASTE	Caste
TSNO	Family size
TRTIME	Time spent in collection of water per day per household in hours
OWNLAND	Size of landholding of the household in hectares

Logistic Regression with Willingness to Pay for the Revival of TWHS and Laying of Piped System

$$\mathrm{P}\,[WTPHS] = 1[Event] = \frac{1}{1} + e^{-Z}$$

$$\mathrm{P}[WTPIP] = 1[Event] = \frac{1}{1} + e^{-z}$$

$$Z = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + ... + \beta_n X_n$$

where,

(i) WTPHS	Households willingness to pay for revival of TWHS
(ii) WTPIP	Households willingness to pay for laying of piped system

Independent Variables:

PCINC	Per capita monthly income
PCEDUEX	Per capita household expenditure on education in Rupees during 2000-01
CASTE	Caste
TSNO	Family size
EDU	Number of formal years of education of the respondent

TRTIME	Time spent in collection of water per day per household in hours
PCHUMQ	Per capita quantity of consumption of water for all purposes by human beings in litres
PCLSQ	Per capita quantity of consumption of water by livestock in litres

Chapter 3

Case Study I: Bavdis of South Western Madhya Pradesh

3.1 Selected Bavdis in Madhya Pradesh

Till recently Barwani and Khargone districts were part of one single district called West Nimar. Barwani district consists of hilly terrain and parts of it form the valley of river Narmada (Map 3.1.1). Due to the undulating terrain the surface run-off of rainwater is high.

3.1.1 Hydrological and Structural Features of Selected Bavdis

Barwani District

Dhababavdi village is located south of Barwani town on the road to Silawat, 11 km from Barwani (Map 3.1.2). There are three bavdis in the village, of which one is a small-dilapidated structure (Plate V1.6.M). The soil cover is only 20 cms in the fields and rest of the terrain is rocky. The stream traversing through the valley carries water to the bavdis and wells along the stream (Plate V1.3.C). The hills are formed of basalt and dolerite having cracks, joints and fractures (Figure 3.1.1).

Sources of Water

There are five hand pumps in the village providing about 16000 litres per day. Three of them typically dry up during summer. There are seven open wells on the bank of the stream; water levels in these wells vary from 5 to 8 meters below ground level. These wells are used for irrigation.

Selected TWHS (Dhababavdi and Jhalabavdi)

The 100 year old Jhala Bavdi is used by the State Forest Department for watering nursery plants (Figure 3.1.3; Plate V1.5.S). The dimensions and pumping details of the bavdi is given in Table 3.1.1.

The main bavdi of the village, namely Dhababavdi, is located near the old Dargah, on the bank of the stream (Figure 3.1.2; Plate V1.1.S). One monoblock electric motor has been installed in this bavdi and the water is used for private irrigation purpose (Plate V1.2.S). The dimensions of the bavdi are provided in Table 3.1.2.

Table 3.1.1: Structural Dimensions of Jhalabavdi

Details	Dimensions
Type of TWHS	Bavdi
Length	3.50m
Breadth	3.20m
Depth	15.50m
Water level	1.20m (bmp)
Total depth	3.10m (bmp)
Water tank	1.80 x 1.20 x 1.20
Time taken	30 minutes
Discharge rate	1.44 lps
Oil engine	7.5 HP
Installed	On top of Bavdi
Total pumping	90 minutes
Pumping Hours	6 Hrs.(Monsoon)
Volume of water	7.776 m^3 (on April 15, 2002)
Volume of water (approximately)	31.104 m^3 (in October, 2001)
Volume of water (approximately)	10.00 m^3 (in June,2001)
Use at present	Nursery

Source: Field Survey, 2002

Table 3.1.2: Structural Dimensions of Dhababavdi

Details	Dimensions
Type	Bavdi
Length	4.15m
Breadth	4.85m
Depth	10.20 m
Water level	2.75 m (bmp)
Depth	6.85 m (bmp)
Water column	4.10 m
Pumping hours	90 minutes
Pump/Motor	EM 3 HP
Installed at	Bavdi steps
Suction/delivery	63mm x 50mm
Discharge rate	15.28 lps
Volume of water	82.52 m^3 (On April 15, 2002)
Volume of water	275.00 m^3 (up to October, 2001)
Volume of water (approximately)	20.00 m^3 (in June, 2001)
Use at present	Irrigation

Source: Field Survey, 2002

Khargone District

Khargone district falls between latitude 21° 25' to 22° 35' north and longitude 74°19' to 76° 12' east. Total area of Khargone district is 8309 sq km (Map 3.1.3). Physiographically Khargone district can be broadly divided into three distinct natural divisions. Parallel with the Narmada river lie the marked belts of Narmada valley in the centre of Satpura range. The valley north of Narmada forms a low-lying tract drained by several streams. The valley south of Narmada slopes gradually towards the river studded with domes and low hills. One small river Kunda flow from south to north near Khargone and merge into Beda River. Normal average rainfall of Khargone district (1976 to 1997) is 831.5 mm. Maximum temperature reaches 42°C and minimum temperature dips to 1°C.

Major part of Khargone district consists of Deccan trap basalt hard rocks. Information on groundwater levels of Khargone district along with rainfall data is presented in Table 3.1.3. Average rise in groundwater levels from 1987 to 1997 is 4.27m. Hydrologically the water level rise indicates recharge to groundwater body and the fall in water level indicate the draft of groundwater.

Table 3.1.3: Rainfall and Groundwater Level, Khargone

Year	Rainfall (mm)	WL		
		In May (m)	In November (m)	Rise (m)
1987	471.7	9.97	6.86	3.11
1988	1247.4	10.06	4.42	5.64
1989	782.0	8.62	5.91	2.71
1990	1084.3	9.08	4.80	5.50
1991	647.4	8.41	6.81	1.60
1992	825.6	10.01	7.39	2.62
1993	1096.5	8.96	5.00	3.96
1994	1224.0	9.83	5.33	4.50
1995	691.2	11.20	5.26	5.94
1996	785.3	10.18	4.39	5.79
1997	791.2	10.31	4.71	5.60

Source: *CGWB District Report, Khargone, 2000*

In Khargone district the traditional drinking water harvesting structures were bavdis that are open wells having steps built to fetch groundwater. Village Temla of Khargone district is selected as the sample case of Bavdis.

Temla village is located in the north west of Khargone town at a distance of 9 kilometres. Temla village falls at Latitude 21°52'15" north and Longitude 75°34'35"east (Figure 3.1.4). Topography of the village is gently undulating with high grounds occurring at north west of village. Surface contours of 300 metres and 280 metres indicate that the topographic slope is from northwest to southeast. One small stream originating from these hillocks traverses southeast, turns northeast and after passing through Baidia village merges in river Kunda east of Pipalia. A small hillock is formed in the east of village from where one drainage course emanate and traverse southwards. The village area has black cotton soil in the agriculture fields, which is typical of the basaltic terrain. Typical soil profile of Temla village is given as under.

0.00 - 0.30 m	Black, clay loamy
0.30 - 1.50 m	Kankary clay
1.50 - 2.50 m	Weathered basalts
2.50 - > 5 m	Massive rock

Hard rocks of basalt occur in and around Temla village. Basalt rocks are basic igneous rocks having joints, cracks and fissured zones. These rocks are not considered as potential ground water bearing aquifers. Groundwater in and around Temla village flows through cracks, fractures and weathered zones of hard rocks of basalt. Hard rocks are exposed right from the ground level and most of the rainfall passes through the village as runoff and flows out through small drains and merge into the main drainage system (Plate V2.3.C). Rainwater seeps underground through cracks and joints whenever it comes across fractures and weathered zones.

Sources of Water

There are three boreholes in the village, each has been installed with India Mark II hand pumps. These are located at Temla Ramangaon road, near Mataji ki Deri and Village school and supply water at the rates of 0.3 lps, 0.2 lps and 0.1 lps, respectively. Further, the village aslo has three deep boreholes (Tubewells). The details of water supply through these sources have been provided in Table 3.1.4.

However, the groundwater availability was expected to decline during May and June to 50,000 litres per day. As reported by the villagers, during the 1970s hand pump on a bore hole of 60 metres depth could draw groundwater; presently, this level has gone beyond 120 metres.

Table 3.1.4: Estimated Supply of Water in the Tube Wells and Hand Pumps of Temla, April 2002

Structure	Discharge Lps	Hours per day	Volume m^3 per day
Tubewell 1	3	6	64.80
Tubewell 2	2	6	43.20
Tubewell 3	1.5	6	32.40
Hand pump 1	0.3	8	8.640
Hand pump 2	0.2	8	5.760
Hand pump 3	0.1	8	2.880
Total			157.68m^3

Source: Field Survey, 2002

Selected TWHS (Temla Bavdi)

The Temla bavdi located in the north of village, on Temla – Ramangaon road. This bavdi is 3.50m in diameter and 10.50 meter deep (Plate V2.1.S). It is lined with stone masonry upto 4.65 m and then hard basalt rock is exposed in the bavdi. Hard rock is also exposed in the bottom (Figure 3.1.5). One bore hole had been drilled in the bavdi by the villagers, but failed. As such the bavdi is being used as a storage tank to retain water pumped from the tubewell, drilled 3 km north west of the village. Villagers informed that after the rainfall the Bavdi attains a water level of 5 metre bgl. This 5 meters column of water is used for cattle for 50 days and then on the bavdi is used as a storage tank (Plate V2.4.U). Water brought from the tubewell fills the bavdi and then is pumped to an overhead tank with a capacity of 45,000 litres, built for supplying water to village Temla, through a pipeline network (Plate V2.2.S).

3.1.2 Quality of Water

Barwani District

Water samples were collected from Dargah hand pump, Jhalabavdi and Dhababavdi. Chemical analysis results (Table 3.1.5) indicate that all these water samples are fit for human consumption. Bacteriological analyses of the water samples from the two bavdis, namely Jhalabavdi and Dhababavdi, were also carried out to establish the nature of purity and potability of water from these sources. Table 3.1.6 presents the results of bacteriological tests of the water samples from both the bavdis and both the samples were found to be unfit for drinking purposes. The concentration of coliform bacteria in both the samples was as high as 2400 mpn/ 100 ml of water. The water from both the sources should essentially be treated with chlorine and other chemical disinfectants, as mere boiling and filtering would not render it potable.

Table 3.1.5: Chemical Analysis of Water Samples from Dhababavdi

Sample No.	1	2	3
Well/Bore	Dhababavdi	Jhalabavdi	Hand Pump (Dargah)
Village	Dhababavdi	Dhababavdi	Dhababavdi
Tehsil	Barwani	Barwani	Barwani
District	Barwani	Barwani	Barwani
Depth	15 m	12 m	90 m
SWL	11.20 m	6 m	40 m
EC mmhos/cm	720	730	650
pH	7.6	7.5	7.5
TDS (ppm)	520	540	480
Calcium (Ca)	55/2.75	65/3.25	60/3.00
Magnesium (Mg)	36/3.00	30/2.50	27/2.25
Sodium (Na)	33/1.43	36/1.57	29/1.26
Carbonate (CO_3)	Nil	Nil	Nil
Bicarbonate (HCO_3)	Nil	Nil	Nil
Sulphate (SO_4)	82/1.70	96/2.00	77/1.60
Chloride (Cl)	24/0.68	16/0.45	16/0.45
Remarks	*Suitable for use*	*Suitable for use*	*Suitable for use*

Table 3.1.6: Bacteriological Test Results of Water Samples, Dhababavdi

Sample/ Characteristics	Biological mpn per 100 ml	Cause of Rejection (if any)	*Remarks*
Dhababavdi	2400 mpn	10 Coliform bacteria	*Not fit for drinking*
Jhalabavdi	2400 mpn	10 Coliform bacteria	*Not fit for drinking*

Khargone District

The chemical analysis of Temla water sources indicate that the hand pump and tubewell water is fit for drinking (Table 3.1.7). The bacteriological analysis of the water samples from Hand pump and Borehole is presented in Table 3.1.8; suggesting that bacterial concentration of coliform bacteria is negligible in the water sample and hence the water is fit for drinking. It may be noted that the water from the borehole is temporarily stored in the bavdi before being pumped into the distribution tank.

Table 3.1.7: Chemical Analysis of Water Samples from Temla

Sample No.	1	2
Well/Bore	Hand Pump Temla Ramangaon Road	Borehole Temla Ramangaon Road
Village	Temla	Temla
Tehsil	Khargone	Khargone
District	Khargone	Khargone
Depth	120m	160m
SWL	45m	52m
EC mmhos/Cm	750	560
PH	7.5	8.1
TDS ppm	520	410
Calcium (Ca)	65/3.25	45/2.25
Magnesium (Mg)	27/2.25	6/0.50
Sodium (Na)	46/2.00	66/2.87
Carbonate (CO_3)	Nil	Nil
Bicarbonate (HCO_3)	220/3.60	183/3.00
Sulphate (SO_4)	110/2.29	91/1.90
Chloride (Cl)	56/1.58	24/0.68
Remarks	*Suitable for Use*	*Suitable for Use*

Table 3.1.8: Bacteriological Test Results of Water Sample, Temla

Sample/ Characteristics	Biological mpn per 100 ml	Cause of Rejection (if any)	*Remarks*
Temla Bavdi	43 mpn per 100 ml	10 Coliform Bacteria	*Fit for drinking*

3.2 Socio-Economic Characteristics of Sample Villages

Between the two sample villages Temla in Khargone is better endowed in terms of basic amenities as may be seen from Table 3.2.1. Information on the basic socio-economic characteristics of the population of sample villages has been presented in Tables 3.2.2 through 3.2.6. In terms of occupation agricultural activities remain the predominant source of income in both the villages. However, with practically the same household size for both the villages, in Dhababavdi the average landholding size is far below (almost half) that of Temla. Similarly almost all the surveyed households in Dhababavdi fall in the income class of below Rs 4000 per month. In terms of social classes a high 92 per cent of the total population in Dhababavdi belong to Scheduled Tribes (ST) whereas the predominant social group in Temla comprises Other Backward Castes (OBC).

Table 3.2.1: Basic Amenities in the Sample Villages, Madhya Pradesh

Amenities	Villages	
	Dhababavdi	Temla
Roads	Kutcha (to DR, 1km)	Pucca (to SH, 0.5 km)
Bus Services	Private, thrice a day	10-12 a day, Pvt. and Pub.
Schools	Primary	Primary (1) Secondary (1)
Medical Facilities	Subcentre (3 km)	Subcentre
Post Office	Branch PO (3 km)	Branch PO
Telephone	PCO (3 km)	PCO, Pvt.
Market	APMC (11km)	APMC (10km)
Community Gathering Places	Well	Panchayat and School

Source: Field Survey, 2001

Table 3.2.2: Population Profile of Sample Villages, Madhya Pradesh

Particulars	Villages	
	Dhababavdi	Temla
Population	514 (50.0)	587 (47.53)
Population (0-6)	112 (57.14)	109 (44.04)
Scheduled Castes	6 (66.7)	233 (49.78)
Scheduled Tribes	459 (49.23)	-
Literates	27 (29.63)	151 (23.84)

Source: *District Census Handbook, Khargone, 1991*
Note: Figures in parentheses indicate percentage of female population.

Table 3.2.3: Distribution of Workers in the Sample Villages, Madhya Pradesh

Particulars/Villages	Dhababavdi		Temla	
	Males	Females	Males	Females
Main Workers	151	145	166	138
Cultivators	137	128	62	48
Agricultural Labourers	11	16	88	88
Livestock & Allied Activities			2	
Mining & Quarrying				
Household Industry			3	
Construction	2			
Trade and Commerce			2	1

Transport Storage and Communication				
Other Services	1	1	9	1
Marginal Workers			5	16
Non workers	106	112	137	125

Source: *District Census Handbook, Khargone, 1991*

Table 3.2.4: Caste and Family Size of Sample Households in the Sample Villages, Madhya Pradesh

Particulars	Dhababavdi	Temla
Number of households	50	57
Population	336	348
Family Size	6.7	6.1
Caste:		
SC	4 (8.0)	8 (14.0)
ST	46 (92.0)	1 (1.8)
OBC	-	43 (75.4)
General	-	5 (8.8)

Source: Field Survey, 2001

Note: Figures in parentheses are proportions to the total number of sample households in the village.

Table 3.2.5: Income Classes of Sample Households, Madhya Pradesh

Village	Income Groups (Monthly Income in Rupees)				
	< 1000	1000-4000	4001-8000	> 8000	All
Dhababavdi	17 (34.0)	31 (62.0)	2 (4.0)	-	50 (100.0)
Temla	10 (17.5)	28 (49.1)	10 (17.5)	9 (15.8)	57 (100.0)

Source: Field Survey, 2001

Note: Figures in parentheses are proportions to the total number of sample households in the village

Table 3.2.6: Landholding Status of the Sample Households, Madhya Pradesh

Landholding	Villages (No. of households)	
	Dhababavdi	Temla
Average Landholding (in hectares)	0.97	1.83
<1 ha (Marginal)	30	9
1-2 ha (Small)	4	12
2-10 ha (Medium)	2	19
>10 ha (Large)	1	-
Landless	13	17

Source: Field Survey, 2001

3.2.1 Consumption Pattern and Dependence on TWHS

An idea about the per capita level water consumption pattern in both the villages is presented in Table 3.2.7. Based on standard norms of water use the total deficiency of water availability per household is much higher (46 per cent) for Dhababavdi compared to Temla (29 per cent). An important observation that may be made here relates to the existence of substantial demand for water for livestock consumption in these villages. Sourcewise and purposewise dependence of households in the sample villages for water for domestic purposes and livestock has been given in Tables 3.2.8 through 3.2.11. The dependence on modern sources is quite substantial as the vavdis are either small in size or are in private control as in Dhababavdi. Also, it needs to be noted that the bavdi in Temla is being used as a storage tank for water pumped in from a distant tubewell; hence, all the users considered the quality of water to be good for drinking and other domestic purposes. The perception about the quality of water in the bavdis of Dhababavdi varied, as shown in Table 3.2.12.

Table 3.2.7: Demand Pattern for Domestic Water Use in Sample Villages, Madhya Pradesh

(litres per day)

Purpose	Dhababavdi		Temla	
	Total Qty Used	Per Capita Qty Used	Total Qty Used	Per Capita Qty Used
Drinking Human	2302	6.85	3175	9.12
Cooking	1005	2.99	1297	3.73
Bathing Males	1350	15.00	2032	15.75
Bathing Females	1207	15.68	2005	17.43
Bathing Children	1662	9.83	1435	13.80
Washing Clothes	2875	8.56	3785	10.88
Washing Utensils	1210	3.60	1512	4.34
Latrine	717	2.13	1248	3.586
Drinking Animals	655	2.78	65	0.33
Washing Animals	470	2.76	180	0.92
All Purposes	13453	23.52	16734	30.70
Standard Quantity (Human)	17200		17440	
Standard Quantity (Livestock)	6890		5845	
Deficiency (Human)	4872 (28.33)		951 (54.53)	
Deficiency (Livestock)	6235 (90.49)		5845 (100.00)	
Total Deficiency	11577 (46.11)		6976 (29.19)	

Source: Field Survey, 2001

Notes: Standard quantity for human consumption is based on the criterion of 40 lpcd (litres per capita per day)

Standard quantity for livestock (cattle at 30 lpcd and sheep & goat at 10 lpcd)

Total deficiency includes deficiency for human and livestock consumption plus the actual quantity of water used for animal washing.

Figures in parentheses are the percentage of deficiency towards standard quantity required.

Table 3.2.8: Percentage Distribution of Water Use by Source and Purpose in Madhya Pradesh (Percentages)

Purpose/ Source	Dhababavdi			Temla					
	Bavdi	Well	Hand pump	Bavdi	Private Tap	Talav	Well	Handpump	Stand Post
Drinking Human	18.84	20.26	15.28	11.90	25.04	17.72	19.35	7.36	42.76
Cooking		7.77	7.61	4.76	9.53	8.86	16.13	4.05	15.13
Bathing Males	14.49	10.21	9.75		12.04	10.13	12.90	13.55	9.87
Bathing Females	5.80	8.83	9.18		12.07	10.13	12.90	13.30	7.89
Bathing Children		11.92	13.11		7.03	7.59	38.71	11.38	3.95
Washing Clothes		21.28	22.30	23.81	15.51	22.78		35.05	13.16
Washing Utensils		8.83	9.45	7.14	8.28	12.66		10.54	7.24
Latrine		4.09	6.24		10.22	10.13		4.77	
Drinking Animals	31.88	4.36	4.04	9.52	0.28				
Washing Animals	28.99	2.45	3.03	42.86					
Total*	345 (100.0)	4699 (100.0)	8409 (100.0)	420 (100.0)	9027 (100.0)	395 (100.0)	155 (100.0)	5977 (100.0)	760 (100.0)

Source: Field Survey, 2001

Note: * Quantity in litres per day

Table 3.2.9: Purpose-wise Proportion of Demand for Water Met by Different Sources in Sample Villages, Madhya Pradesh

(Percentages)

Purpose/ Source	Dhababavdi				Temla						
	Bavdi	Well	Hand pump	All*	Bavdi	Private Tap	Talav	Well	Hand pump	Stand Post	All*
Drinking Human	2.82	41.36	55.82	2302 (100.0)	1.57	71.18	2.20	0.94	13.68	10.24	3175 (100.0)
Cooking	-	36.32	63.68	990 (100.0)	1.54	66.31	2.70	1.93	18.66	8.87	1297 (100.0)
Bathing Males	3.70	35.56	60.74	1350 (100.0)	-	53.49	1.97	0.98	39.86	3.69	2032 (100.0)
Bathing Females	1.66	34.38	63.96	1207 (100.0)	-	54.36	2.00	1.00	39.65	2.99	2005 (100.0)
Bathing Children	-	33.69	66.31	1662 (100.0)	-	44.25	2.09	4.18	47.39	2.09	1435 (100.0)
Washing Clothes	-	34.78	65.22	2875 (100.0)	2.64	36.99	2.38	-	55.35	2.64	3785 (100.0)
Washing Utensils	-	34.30	65.70	1210 (100.0)	1.98	49.40	3.31	-	41.67	3.64	1512 (100.0)
Latrine	-	26.78	73.22	717 (100.0)	-	73.96	3.21	-	22.84	-	1248 (100.0)
Drinking Animals	16.79	31.30	51.91	655 (100.0)	61.54	38.46	-	-	-	-	65 (100.0)
Washing Animals	21.28	24.47	54.26	470 (100.0)	100.00	-	-	-	-	-	180 (100.0)
Total	2.56	34.93	62.51	13453 (100.0)	2.51	53.94	2.36	0.93	35.72	4.54	16734 (100.0)

Source: Field Survey, 2001
Note: * Quantity in litres per day

Table 3.2.10: Dependence of Sample Households on Selected TWHS (Bavdi) in the Sample Villages, Madhya Pradesh

(No. of Households)

Dependence/ Village	Dhababavdi	Temla
All Purposes	- (0.0)	- (0.0)
Not at all	40 (80.0)	21 (36.8)
Drinking only	1 (2.0)	1 (1.8)
Total No. of Households	50	57

Note: Figures in parentheses are proportion to the total number of sample households.

Table 3.2.11: Demand for Water Met by Traditional and Modern Sources, Madhya Pradesh

(Percentages)

Village	Source			
	Traditional	Modern	Selected TWHS	All
Dhababavdi	34.93	62.51	2.56	100.0
Temla	3.29	94.20	2.51	100.0

Source: Field Survey, 2001
Notes: Sources in Dhababavdi: traditional - wells, modern – hand pumps and selected TWHS – Bavdi.

Sources in Temla: traditional – wells and talav, modern – private taps and hand pumps and selected TWHS – bavdi.

Table 3.2.12: Respondents' Perception of Quality of Water of Bavdis in Sample Villages, Madhya Pradesh

(No. of Households)

Perception About Quality	Dhababavdi
Potable (Good for drinking, cooking and domestic use)	15 (36.6)
Non-potable but used for other domestic purposes	18 (43.9)
Used for domestic purposes but not for cooking and drinking	17 (41.5)
Used only for livestock drinking	1 (2.4)
Non-potable and Unsuitable for any domestic purposes	8 (19.5)
Used but may cause diseases	3 (7.3)
Unsuitable for any domestic purpose	3 (7.3)
Suitable only for irrigation	2 (4.9)

Source: Field Survey, 2001

Note: Figures in parentheses indicate proportion of sample households.

3.2.2 Cost Estimation and Willingness to Pay

The estimates for the revival of the selected bavdis and laying a network for piped water supply, as worked out by the team of hydrogeologist and water works engineers, have been presented in Tables 3.2.11 to 3.2.14. As may be seen from Table 3.2.15 a remarkably low proportion of households were ever willing to pay for the capital costs for either revival of TWHS or installation of piped network or both. The rather interesting finding is that in the relatively poorer village, Dhababavdi, the households willing to pay for either of the facilities were ready to part with 10 per cent of their annual income, whereas, the same was less than 1 per cent in case of Temla. It may be noted that in Dhababavdi most sources of water have practically dried up or yielding very small quantities of water. This has probably prompted even some of the otherwise very poor households to express willingness to pay for the possible provision of water supply. Details of amounts households were willing to pay for the TWHS and piped water system across income and landholding classes have been presented in Tables 3.2.16 through 3.2.21.

Table 3.2.13: Cost Estimates for the Revival of TWHS, Dhababavdi

Particulars	Amount (Rs.)
Estimated Amount of Gabion and Dry Boulder Check Dam	1,14,000
Estimated amount for Talab	4,97,000
Sub-Total	6,11,000
Estimated Cost of Gabian Structure	61,000
Estimated Cost of Dry Boulder Check Dam	15,000
Total	6,87,000

Table 3.2.14: Cost Estimates of Revival of TWHS, Temla

Particulars	Amount (Rs.)
Estimated Amount of Mini Talab	62,000
Estimated Amount of Talab	1,18,000
Estimated Amount of Masonry Check Dam	1,37,000
Estimated amount of Farm Pond and Dry Boulder Check Dam	21,000
Total	3,38,000

Table 3.2.15: Cost Estimates for Laying Piped System, Dhababavdi

Particulars	Amount (Rs.)
Cost of water supply system by pipe connection in the village	1,50,000
Cost of Taps and other expenses	38,000
Total	1,88,000

Note: Estimate prepared by CSR, MP, RES, and SOR effective from October 2 1995.

Table 3.2.16: Cost Estimates for Laying Piped System, Temla

Particulars	Amount (Rs.)
Cost of water supply system by pipe connection in the village	1,50,000
Cost of Taps and other expenses	27,000
Total	1,77,000

Table 3.2.17: Household Level Willingness to Pay for Revival of TWHS and Laying of Piped System, Madhya Pradesh (No. of households)

Village	TWHS			Piped System		Total Number of sample households
	Capital Cost	O & M	Labour	Capital Cost	O & M	
Dhababavdi	11 (26.8)	16 (39.0)	38 (92.7)	9 (22.0)	12 (29.3)	50
Temla	6 (11.8)	39 (76.5)	43 (84.3)	5 (9.8)	7 (13.7)	57

Note: Figures in parentheses are proportions to the total number of sample households in the village.

Table 3.2.18: Proportion of Expenditure on Education, Health and WTP Amounts to the Total Household Income of Sample Households, Madhya Pradesh

(Percentages)

Village	Education	Health	WTP
Dhababavdi	0.73	3.38	10.01
Temla	2.34	4.00	0.78

Table 3.2.19: Frequency Distribution of WTP Amount in the Sample Villages for Revival of TWHS, Madhya Pradesh

Proportion of Amount	Frequency (%)	Average WTP (Rs.)
Dhababavdi		
Nil	23 (56.1)	-
< 25%	6 (14.6)	1283.33
26-50%	3 (7.3)	3333.33
51-75%	-	-
75-99%	-	-
100%	9 (22.0)	8000.0
All Classes	41 (100.0)	2187.81
Temla		
Nil	17 (33.3)	-

< 25%	6 (11.8)	166.67
26-50%	11 (21.6)	500.00
51-75%	-	-
75-99%	-	-
100%	17 (33.3)	1000.0
All Classes	51 (100.0)	460.78

Note: Figures in parentheses are proportions to the total number of sample households in the village.

Table 3.2.20: Willingness to Pay for TWHS Across Income Classes, Madhya Pradesh

(No. of Households)

Income (Rs. Per Month) Range	Proportion of Amount of WTP						
	0	< 25%	26-50%	51-75%	76-99%	100%	All
Dhababavdi							
< 1000	7 (17.1)	1 (2.4)	2 (4.9)			3 (7.3)	13 (31.7)
1000-4000	15 (36.6)	5 (12.2)	1 (2.4)			5 (12.2)	26 (63.4)
4001-8000	1 (2.4)					1 (2.4)	2 (4.9)
>8000							
All classes	23 (56.1)	6 (14.6)	3 (7.3)			9 (22.0)	41(100.0)
Temla							
< 1000	4 (7.8)	1 (2.0)	3 (5.9)				8 (15.7)
1000-4000	12 (23.5)	4 (7.8)	3 (5.9)			5 (9.8)	24 (47.1)
4001-8000		1 (2.0)	4 (7.8)			5 (9.8)	10 (19.6)
>8000	1 (2.0)		1 (2.0)			7 (13.7)	9 (17.6)
All classes	17 (33.3)	6 (11.8)	11 (21.6)			17 (33.3)	51 (100.0)

Note: Figures in parentheses are percentages to the total number of sample households in the respective villages.

Table 3.2.21: Willingness to Pay for TWHS Across Landholding Classes, Madhya Pradesh

Landholding classes (in hectares)	Proportion of Amount of WTP						
	0	< 25%	26-50%	51-75%	76-99%	100%	All
Dhababavdi							
<1 ha (Marginal)	12 (38.7)	3 (9.7)				4 (12.9)	19 (61.3)
1-2 ha (Small)	4 (12.9)	1 (3.2)	1 (3.2)			3 (9.7)	9 (29.0)
2-10 ha (Medium)	1 (3.2)	1 (3.2)					2 (6.5)
>10 ha (Large)	1 (3.2)						1 (3.2)

All classes	18 (58.1)	5 (16.1)	1 (3.2)			7 (22.6)	31* (100.0)
Temla							
<1 ha (Marginal)	6 (16.2)		1 (2.7)				7 (18.9)
1-2 ha (Small)	2 (5.4)	3 (8.1)	2 (5.4)			4 (10.8)	11 (29.7)
2-10 ha (Medium)	5 (13.5)		4 (10.8)			10 (27.0)	19 (51.4)
>10 ha (Large)							
All classes	13 (35.1)	3 (8.1)	7 (18.9)			14 (37.8)	37* (100.0)

Note: Figures in parentheses are percentages to the total number of sample households in the respective villages.

* Total Number of Households does not include landless households i.e. 10 in Dhababavdi and 14 in Temla village.

Table 3.2.22: Willingness to Pay for Piped System Across Income Classes, Madhya Pradesh

Income (Rs. Per Month) Range	Proportion of Amount of WTP						
	0	< 25%	26-50%	51-75%	76-99%	100%	All
Dhababavdi							
< 1000	10 (24.4)		1 (2.4)			2 (4.9)	13 (31.7)
1000-4000	18 (43.9)			1 (2.4)		7 (17.1)	26 (63.4)
4001-8000	2 (4.9)						2 (4.9)
>8000							
All classes	30 (73.2)		1 (2.4)	1 (2.4)		9 (22.0)	41 (100.0)
Temla							
< 1000	6 (11.8)					2 (3.9)	8 (15.7)
1000-4000	20 (39.2)		1 (2.0)			3 (5.9)	24 (47.1)
4001-8000	10 (19.6)						10 (19.6)
>8000	9 (17.6)						9 (17.6)
All classes	45* (88.2)		1 (2.0)			5 (9.8)	51 (100.0)

Note: Figures in parentheses are percentages to the total number of sample households in the respective villages.

* 39 households in the village own a private tap, therefore number of households *not* willing to pay for piped system is as high as 88.2 per cent.

Table 3.2.23: Willingness to Pay for Piped System Across Landholding Classes, Madhya Pradesh

Income (Rs. Per Month) Range	Proportion of Amount of WTP						
	0	< 25%	26-50%	51-75%	76-99%	100%	All

Dhababavdi							
<1 ha (Marginal)	13 (41.9)		1 (3.2)	1 (3.2)		4 (12.9)	19 (61.3)
1-2 ha (Small)	7 (22.6)					2 (6.5)	9 (29.0)
2-10 ha (Medium)	2 (6.5)						2 (6.5)
>10 ha (Large)						1 (3.2)	1 (3.2)
All classes	22 (71.0)		1 (3.2)	1 (3.2)		7 (22.6)	31 (100.0)
Temla							
<1 ha (Marginal)	6 (16.2)					1 (2.7)	7 (18.9)
1-2 ha (Small)	11 (29.7)						11 (29.7)
2-10 ha (Medium)	18 (48.6)		1 (2.7)				19 (51.4)
>10 ha (Large)							
All classes	35 (94.6)		1 (2.7)			1 (2.7)	37 (100.0)

Note: Figures in parentheses are percentages to the total number of sample households in the respective villages.

* Total Number of Households does not include landless households i.e. 10 in Dhababavdi and 14 in Temla village.

3.2.3 Factors Affecting Consumption of Water and Willingness to Pay

Consumption of Water

The results of multiple regression with per capita consumption of water have been presented in Table 3.2.24. The two variables, which were found to be significant, were per capita monthly income (PCINC) and the family size (TSNO) of sample households.

Table 3.2.24: Results of Multiple Regression with Per Capita Consumption of Water (CONWAT) as Dependent Variable, Madhya Pradesh

Independent Variables	Standardized Coefficients	t	Sig.
Constant	-	11.150	0.000
PCINC	0.188**	1.994	0.049
CASTE	0.121	1.277	0.205
TSNO	-0.621*	-7.522	0.000
TRTIME	0.049	0.608	0.545
OWNLAND	0.057	0.684	0.496

Adjusted R Square = 0.461
Computed F Value = 16.588 Significance = 0.000
Degrees of Freedom = 91 (Total)
* Significant at 1 per cent level
** Significant at 5 per cent level

Willingness to Pay for Revival of TWHS

The per capita quantity of consumption of water for all purposes by human beings in litres (PCHUMQ) was the only variable appearing to be statistically significant factor affecting the willingness to pay for the revival of TWHS (WTPHS). The results of logistic regression are presented in Table 3.2.25.

Table 3.2.25: Results of Logistic Regression with Willingness to Pay for the Revival of TWHS (WTPHS) as the Dependent Variable, Madhya Pradesh

Independent Variable	Standard error	Wald	Df	Sig	Exp (B)
PCINC	0.001	0.453	1	0.501	1.001
PCEDUEX	0.002	0.265	1	0.607	1.001
TSNO	0.145	2.701	1	0.100	1.269
CASTE	0.597	0.352	1	0.553	1.425
TRTIME	0.066	2.673	1	0.102	0.897
EDU	0.099	0.673	1	0.412	1.085
PCHUMQ	0.020	3.035	1	0.081	1.035***
PCLSQ	0.057	0.319	1	0.572	0.968
Constant	1.951	1.315	1	0.251	0.107

Nagelkerke R square = 0.280
Cox & Snell R Square = 0.202 Significance = 0.082
Degrees of Freedom = 8 (Model)
*** Significant at 10 per cent level

Chapter 4

Case Study II: Wells of Western Rajasthan

4.1 Selected Wells in Rajasthan

4.1.1 Hydrological and Structural Features of Selected Wells

Barmer District

The total geographical area of Barmer district is 28387 km^2. Barmer district of Rajasthan falls between latitudes 24° 45' to 26°35' North and Longitudes 70°20' to 73°20' east. Barmer district is part of the vast Thar district, where dry farming is prevalent in rural areas (Map 4.1.1). Average annual rainfall of Barmer district (1991-2000) is 308.4mm (Pachpadra station). The district has rock types as calcrete, silcrete, gypseferous bed, and claystones as typical desert geology. Scattered outcrops of granite and rhyollite are found at different places. Calcrete, silcretes and claystones, the prevalent rock types of Barmer district do not make potential groundwater aquifers. The desert underground strata are poor in groundwater storage and transmission. Deep groundwater of the district is saline. Table 4.1.1 indicates the depth to water level in observation open well of Kalyanpur (Map 4.1.2). Minor fluctuation in the water level in the generally saline groundwater conditions indicates unfavourable conditions for recharge through rainfall.

Table 4.1.1: Rainfall and Groundwater Levels, Barmer

Year	Rainfall Pachpadra (mm)	WL		
		In May, Kalyanpur (m)	In November, Kalyanpur (m)	Rise (m)
1991	144	23.97		
1992	430	24.12	23.40	0.72
1993	231	23.66	23.42	0.24
1994	430	23.60	21.60	2.00
1995	401	23.52	23.50	.02
1996	216	NA	23.48	NA
1997	384	23.50	23.48	.02
1998	341	23.43	NA	NA
1999	283	23.43	23.25	.18
2000	224	23.40	NA	NA

Source*: CGWB Records, 2001*
NA : Not Available

Nagana village of Pachpadra Tehsil, Barmer district is situated west of Jodhpur City at a distance of 50 kms from Jodhpur on Jodhpur Barmer road. Nagana village falls at latitude 27°7'30" and longitude 72°35' east (Figure 4.1.1). Nagana village has high incidence of scattered reddish brown rhyollite hills. The height of these hills is about 30 to 60 metres. The soil type of Nagana village is sandy silt and followed by clay nature.

A typical soil profile is given here.

0.00m - 0.20m	Coarse red sand
0.20m - .50 m	Medium to fine red silt sand
.50m - 1.50 m	Silt clay
1.50m - > 5 m	White coloured calcrete, clay

The soil profile differs as per the location of the field from where soil profile is taken. Nearer to rhyollite hills the soil profile changes to

0.00m - 0.30 m	Coarse red sand
0.30m - 1.00 m	Weathered rhyollite red coloured.
1.00m - >5.00m	Hard rhyollite

Nagana village and its surrounding area has undulating topography made by hill ranges around the village making pathways for drainage courses forming from hill ranges. One large stream traverses near the village (Plate V3.6.C). The exposures of rhyollite hills with one stream emanating from these hills create favorable situation for ground water recharge. Rhyollite exposures have closed spaced joints and fractures, which act as channel way for groundwater movement. Such fracturing of rock is not uniform throughout, but confined to certain patches only. Groundwater movement through such fractures receives rainfall recharge through drainage and such locations are favourable site for open wells. On such favourable site is located the traditionally old open well of Nagana village, the sample case of this study. Table 4.1.2 provides the discharge capacity of the Nagana well. Rajasthan water supply department has dug new open well near the stream to a depth of 30 metres and lined it with RCC rings to its total depth. The open well has a water level of 27 metres.

Table 4.1.2: Volume of Water Supply from Well, Nagana

Discharge Lps	Hours	Volume/Day Lpd	Volume/year tcm/Year
4	6	86400 litres	31.536 tcm/ year

Source: Field Survey, 2002

Nagana Open Well

One deep open well of 30 m depth, 3 m diameter was dug near the stream (Plate V3.2.S). The open well is lined throughout with pink coloured rhyollite slabs (Plate V3.1.S). There is a large cavity in the well at the bottom of the well. One automatic submersible pump of 15 HP has been lowered in the well (Figure 4.1.2; Plate V3.3.S). Water drawn from the well is being used for water supply to the villagers of Nagana. Table 4.1.3 gives the details. Discharge rate of the well is 4 lps, pumping about 86,000 litres per day.

Table 4.1.3: Structural Dimensions of the Well, Nagana

Details	Dimensions
Diameter	3 m
Depth	30 m
Water level	26.20 m
Submersible pump	15 HP
Installed at	28 m
Pumping hours	6
Discharge rate	4 lps
Volume of water	86400 litres

Source: Field Survey, 2002

Sevalia Nadi

Nadi is a local name for the long embankment raised against the ground slopes to arrest surface run off (Plate V3.4.C). Sevalia nadi is situated in the north of village Nagana probably recharging the water supply well. The recharge process takes place through the close spaced joints and fractures in the rhyollite exposures. This nadi is 120m long and 8m wide. The catchment area is about 400 hectares.

Undaria Nadi

The length of the nadi is 120m. The outflow (spillway) section is damaged and the talav does not store water at present. The nadi can store 3000m^3 of water. Revival of the nadi will help wells down stream.

Pilundia Nadi

This is an old big nadi near village Mandli. The structure is 300m long and 6 metres wide with a large catchment of 500 hectares (Plate V3.5.C). At present this nadi does not store water and embankments have broken. When revived this nadi will store about 20,000 m^3 of water.

Jodhpur

Jodhpur district of Rajasthan is located in the western part of the state falling between latitude 25° 53' to 27° 30' north and longitude 71°52' to 74° east. Total geographical area of Jodhpur district is 22950 sq. km consisting of 7 tehsils and 863 villages (Map 4.1.3). The average annual rainfall during 1991-99 of Jodhpur district is 472 mm of Bhopalgarh station (Map 4.1.4). Groundwater levels of one observation station, Kumbharia is also given in Table 4.1.4.

Table 4.1.4: Rainfall and Groundwater Levels, Godavas

Year	Rainfall Bhopalgarh (mm)	WL		
		In May, Kumbharia (m)	In November, Kumbharia (m)	Rise (m)
1991	318	28.63		
1992	518	31.25	29.97	1.28
1993	268	26.31	30.19	- 3.88
1994	608	34.62	32.62	2.00
1995	577	34.00	33.40	0.60
1996	683	35.25	33.95	1.30
1997	602	33.40	28.96	4.44
1998	367	32.90		
1999	309	23.43	23.25	.18
2000	252	23.40		

Source: *CGWB Records, 2001*

Due to salinity in groundwater in this area of Thar Desert, water levels of observation wells do not clearly indicate the resource condition. Geohydrological conditions around Bhopalgarh indicate possibility of drilling shallow tubewells of 100 metres depth. Absence of any major river and salinity of groundwater make conditions difficult on water supply front. Earlier hand pumps were used for water supply in some villages, but hand pumps have become saline or dry.

The second village selected, to study traditional water harvesting structure in form of open well, is Godavas of Jodhpur district, Bhopalgarh Tehsil. Godavas village is situated at a distance of 47 kilometre on Jodhpur - Bhopalgarh road and the village is located at latitude 26°30' north and longitude 73°28' east as per the Survey of India map (Figure 4.1.3). Topography of Godavas is a very gently sloping flat land typical of Thar Desert landscape. Groundwater is not used for agriculture because of salinity problem. At few places villagers have drilled tubewells to a depth of 80 to 100 metres, but because of lowering of water levels in tubewells and occurrence of hard rhyollite after 100 metres depth, the discharge in tubewells have decreased. The soil type of Godavas village is typical of the desert terrain. The rock types are calcrete, clay stone fine sandstones, claystones and hard rocks of rhyollites at depth below 90-100 metres depth. The soil type is silt clay loam. Soil profile is given as under:

0.00m - 0.30m	Pinkish white fine sand
0.30m - 1.00m	Silky clay loam
1.00m - 3.00m	Calcrete
3.00m - > 5m	Calcrete/Silcrete/claystone

Tubewells

Three tubewells at Badadi village about 5 kilometers from Godavas supply water to seven villages catering about 3500 people. Depths of the tubewells are around 106 metres and the water level is 70 metres. The submersible pumps are lowered at 80 metres. As per the villagers the water levels were at 35 metres before 15 years. With the falling rate of water level, 3 metres per year, the life of the tubewell is only five years. At 106 metres hard rock of rhyollite encounter in the drilling thus making the depth restricted to the rock strata. The water supply situation in this scheme is given as under.

Table 4.1.5: Water Supply from Tubewell, Godavas

Details	Dimensions
Discharge from one tubewell	15000 lph
Discharge from one tubewell	105000 lpd if pumped for 7 hours
Discharge from three tubewell	315000 lpd
Population of seven villages	3000 souls
Population of cattle	5000
Requirements of water/head/d	3000*40= 120000 lpd
Requirement of water/head/d	5000*30 = 150000 lpd
Total Requirement	= 270000 lpd

Source: Field Survey, 2002

Table 4.1.6: Dimensions of Tubewell, Godavas

Details	Dimensions
Water column available today	35 metres
Submersible pump installed at	80 metres
Depth of tubewell available	106 metres
Water column left	26 metres
Effective water column	18 metres
Rate of WL declination	3 metres
Groundwater available for	5 years

Source: Field Survey, 2002

Godavas Well

The dimensions of the structure along with the pumping machinery details are given in Table 4.1.7 (Plate V4.1.S). The diagrammatic representation of the well has been presented in Figure 4.1.4.

Table 4.1.7: Dimensions of Well, Godavas

Details	Dimensions
Diameter	3 m
Depth	27.55 m
Water level	25.20 m
Oil engine	8 HP
Installed at	on top of well
Centrifugal pump at	24 m
Pumping hours	45 minutes
Discharge rate	3 lps
Volume of water drawn in 45 minutes	8100 litres

Source: Field Survey, 2002

As per information gathered from villagers after the rains i.e. upto the month of October the open well can be pumped for 5 hours a day (Plate V4.2.S). During this period a volume of 54000 litres is available against the requirement of 92000 liters per day (Plate V4.5.U).

Godavas Nadi

The embankment wall of the Nadi is 1200 metres long and 8 metres wide (Plate V4.3.C). Rainwater is stored in the Nadi in three different pits. In the year 2001 one pit of 50m X 50m was dug to 1.5 metres depth, but the digging is incomplete. The recharge through the structure may benefit the old openwell, which is situated across the road and may also increase input to shallow tubewells of village. If three pits of $2500 m^2$ area are dug to a depth of 1.5 m and when full the nadi will store $11000 m^3$ of water. The overflow spillway structure is 30 metres long and 4 metres wide (Plate V4.6.M). The spillway structure needs repairs.

Indokia Nadi

There is a small water harvesting structure constructed in the east of village. The Nadi is about 30 metres long and silted up (Plates V4.4.C).

4.1.2 Quality of Water

Barmer

The water from Nagana well was found suitable for use through the chemical analysis of its sample (Table 4.1.8). The bacteriological analysis of the sample, however, revealed that coliform bacteria were present in very high concentrations; the water needs to be treated with chlorine or bleaching powder so as to render it potable. Test results are given in Table 4.1.9.

Table 4.1.8: Chemical Analysis of Water Sample from Well, Nagana

Sample No.	1
Well/Bore	Open Well
Village	Nagana
Tehsil	Pachpadra
District	Barmer
Depth	30 m

SWL	26.20 m
EC mmhos/cm	2100
pH	7.7
TDS ppm	1350
Calcium (Ca)	65/3.75
Magnesium (Mg)	52/3.70
Sodium (Na)	170/10.74
Carbonate (CO_3)	Nil
Bicarbonate (HCO_3)	534/9.40
Sulphate (SO_4)	110/2.80
Chloride (Cl)	80/3.51
Remarks	*Suitable For Use*

Table 4.1.9: Bacteriological Test Results of the Water Sample, Nagana

Particulars	Standards of purified water	Test Results (mg/ l) (Except pH)	Variation from standards	*Remarks*
Coliform Organism	10 mpn/ 100 ml	1100 mpn/ 100 ml	1090 mpn/ 10 ml Excess	*Extremely contaminated, needs bleaching powder or chlorination treatment*

Jodhpur

The chemical testing of water samples for both the sources in Jodhpur were found suitable for drinking (Table 4.1.10). The bacteriological test results indicate that the water is contaminated with the presence of coliform bacteria in high concentrations (Table 4.1.11). Bleaching powder or chlorine treatment is necessary for rendering the water potable.

Table 4.1.10: Chemical Analysis of Water Samples from Godavas

Sample No.	1	2 (From Stand post)
Well/Bore	Open Well	Tubewell of Badadi
Village	Godavas	Badadi
Tehsil	Bhopalgadh	Bhopalgadh
District	Jodhpur	Jodhpur
Depth	27.55 m	110 m
SWL	25.20m	50 m
EC mmhos/cm	1800	2050
PH	7.8	7.8
TDS	1310	1380
Calcium (Ca)	55/2.75	55/2.75
Magnesium (Mg)	42/3.50	45/3.75
Sodium (Na)	270/11.74	322/14.00
Carbonate (CO_3)	Nil	Nil
Bicarbonate (HCo_3)	634/10.40	439/7.20

Sulphate (SO_4)	144/3.00	192/4.00
Chloride (Cl)	160/4.51	328/9.24
Remarks	*Suitable For Use*	*Suitable For Use*

Table 4.1.11: Bacteriological Test Results of the Water Sample, Godavas

Particulars	Standards of purified water	Test Results (mg/ l) (Except pH)	Variation from standards	*Remarks*
Coliform Organism	10 mpn/ 100 ml	240 mpn/ 100 ml	230 mpn/ 100 ml Excess	*Highly contaminated, needs bleaching powder or chlorination treatment*

4.2 Socio-Economic Characteristics of Sample Villages

Both the villages surveyed are poorly endowed with basic infrastructural facilities as may be gauged from Table 4.2.1. Most households in these villages pursue agricultural activities as the main occupation (Tables 4.2.2 and 4.2.3). Whereas Nagana in Barmer is predominantly a tribal village with 61 per cent of the households belonging to the ST category, a high proportion (88 per cent) of the households in Godavas belong to disadvantaged social groups, i.e., SCs and OBCs (Table 4.2.4). Further in terms of both household income and landholding status almost all households are severely deprived economically (Tables 4.2.5 and 4.2.6).

Table 4.2.1: Basic Amenities in the Sample Villages, Rajasthan

Amenities	Villages	
	Nagana	Godavas
Roads	Kutcha (to SH, 2 km)	Pucca (to DR, 5km)
Bus Services	Pub. twice a day	Pub. thrice a day
Railway Station		12 km
Schools	Primary (1)	Primary (1)
Medical Facilities	Dispensary	Dispensary (2.5km)
Post Office		2.5 km
Market	APMC (32km)	APMC (57km)
Community Gathering Places	School	Chaupal

Source: Field Survey, 2001

Table 4.2.2: Population Profile of Sample Villages, Rajasthan

Particulars	Villages

	Nagana	Godavas
Population	631 (46)	640 (48)
Population (0-6)	137 (47)	148 (49)
Scheduled Castes	62 (47)	144 (47)
Scheduled Tribes	190 (47)	
Literates	60 (7)	96 (3)

Source: *District Census Handbook, Barmer and Jodhpur, 1991*

Note: Figures in parentheses indicate percentage of female population.

Table 4.2.3: Distribution of Workers in the Sample Villages, Rajasthan

Particulars	Nagana		Godavas	
	Males	Females	Males	Females
Main Workers	175	12	138	15
Cultivators	100	7	111	13
Agricultural Labourers	15	3	4	-
Livestock & Allied Activities	20	1	-	-
Mining & Quarrying	20	-	-	-
Household Industry	3	-	14	-
Construction	-	-	-	-
Trade and Commerce	10	1	2	2
Transport Storage and Communication	-	-	2	-
Other Services	7	-	5	-
Marginal Workers	10	100	15	159
Non workers	155	179	178	135

Source: *District Census Handbook, Barmer and Jodhpur, 1991*

Table 4.2.4: Caste and Family Size of Sample Households in the Sample Villages, Rajasthan

Particulars	Nagana	Godavas
Number of households	41	43
Population	209	267
Family Size	5.1	6.2
Caste:		
SC	3 (7.3)	11 (25.6)
ST	25 (61.0)	1 (2.3)
OBC	9 (22.0)	27 (62.8)
General	4 (9.8)	4 (9.3)

Source: Field Survey, 2001

Note: Figures in parentheses are proportions to the total number of sample households in the village.

Table 4.2.5: Income Classes of Sample Households, Rajasthan

Village	Income Group (Monthly Income in Rupees)				
	< 1000	1000-4000	4001-8000	> 8000	All
Nagana	22 (53.7)	18 (43.9)	-	1 (2.4)	41 (100.0)
Godavas	12 (27.9)	31 (72.1)	-	-	43 (100.0)

Source: Field Survey, 2001

Note: The figures in parentheses are the proportion to the total number of sample households in the village

Table 4.2.6: Landholding Status of the Sample Households, Rajasthan

Landholding	Villages (No. of Households)	
	Nagana	Godavas
Average Landholding (in Hectares)	0.83	0.80
<1 ha (Marginal)	25	22
1-2 ha (Small)	3	10
2-10 ha (Medium)	6	1
>10 ha (Large)		
Landless	7	10

Source: Field Survey, 2001

4.2.1 Consumption Pattern and Dependence on TWHS

A close look at the pattern of consumption of water at the household level, as presented in Table 4.2.7, indicates that about two-fifths of the total water requirements of the households in both the villages are not being met by the existing sources. Further, the overwhelming dependence on traditional sources in both the villages (82 per cent in Nagana and 57 per cent in Godavas) highlights the significance of TWHS as important sources. The dependence of households on selected TWHS in the sample villages for water for domestic purposes and livestock has been given in Tables 4.2.8 through 4.2.11. However, the popular perception about the quality of water of the TWHS particularly in Godavas varied considerably (Table 4.2.12).

Table 4.2.7: Demand Pattern for Domestic Water Use in Sample Villages, Rajasthan

(litres per day)

Purpose	Nagana		Godavas	
	Total Qty Used	Per Capita Qty Used	Total Qty Used	Per Capita Qty Used
Drinking Human	1765	8.44	2087	7.82
Cooking	848	4.06	902	3.38
Bathing Males	983	13.65	1210	14.24
Bathing Females	828	15.62	1227	16.14
Bathing Children	830	9.88	1197	11.29
Washing Clothes	2180	10.43	2815	10.54
Washing Utensils	1065	5.10	1188	4.45
Latrine	144	0.689	853	3.195
Drinking Animals	230	2.64	526	4.92
Washing Animals	195	6.29	252	3.55
All Purposes	9068	30.64	12257	32.77
Standard Quantity (Human)	12000		15880	
Standard Quantity (Livestock)	2610		3220	
Deficiency (Human)	3357 (27.97)		4401 (27.71)	
Deficiency (Livestock)	2380 (91.19)		2694 (83.66)	
Total Deficiency	5932 (39.27)		7347 (37.15)	

Source: Field Survey, 2001

Notes: Standard quantity for human consumption is based on the criterion of 40 lpcd (litres per capita per day)

Standard quantity for livestock (cattle at 30 lpcd and, sheep and goat at 10 lpcd)

Total deficiency includes deficiency for human and livestock consumption plus the actual quantity of water used for animal washing.

Figures in parentheses are the percentage of deficiency towards standard quantity required.

Table 4.2.8: Percentage Distribution of Water Use by Source and Purpose in Rajasthan

(Percentages)

Purpose/Source	Nagana			Godavas			
	Stand Post **	Well	Talav	Stand Post	Well	Talav	Haveda
Drinking Human	10.70	59.88		7.67	22.90	81.82	
Cooking	10.47	3.09	100.00	5.59	8.67	9.09	
Bathing Males	11.58	7.59		9.97	10.05		
Bathing Females	9.96	5.43		9.91	10.34		
Bathing Children	10.10	4.94		6.28	12.51		
Washing Clothes	27.19	9.88		23.98	22.82		
Washing Utensils	13.53	3.70		8.68	10.67		
Latrine	1.88	0.25		13.78	1.25		100.0
Drinking Animals	2.15	4.32		9.14	0.78	9.09	
Washing Animals	2.42	0.93		5.00			
Total*	7428 (100.0)	1620 (100.0)	20 (100.0)	5045 (100.0)	7032 (100.0)	110 (100.0)	70 (100.0)

Source: Field Survey, 2001

Note: * Quantity in litres per day

** The source of water supply for the stand posts is the village well

Table 4.2.9: Purpose-wise Proportion of Demand for Water Met by Different Sources in Sample Villages, Rajasthan

(Percentages)

Purpose/ Source	Nagana				Godavas				
	Stand Post	Well	Talav	All*	Stand Post	Well	Talav	Haveda	All*
Drinking Human	45.04	54.96	-	1765 (100.0)	18.54	77.14	4.31	-	2087 (100.0)
Cooking	91.75	5.90	2.36	848 (100.0)	31.26	67.63	1.11	-	902 (100.0)
Bathing Males	87.49	12.51	-	983 (100.0)	41.57	58.43	-	-	1210 (100.0)
Bathing Females	89.37	10.63	-	828 (100.0)	40.75	59.25	-	-	1227 (100.0)
Bathing Children	90.36	9.64	-	830 (100.0)	26.48	73.52	-	-	1197 (100.0)
Washing Clothes	92.66	7.34	-	2180 (100.0)	42.98	57.02	-	-	2815 (100.0)
Washing Utensils	94.37	5.63	-	1065 (100.0)	36.87	63.13	-	-	1188 (100.0)
Latrine	97.22	2.78	-	144 (100.0)	80.14	10.51	-	9.35	853 (100.0)
Drinking Animals	69.57	30.43	-	230 (100.0)	87.64	10.46	1.90	-	526 (100.0)
Washing Animals	92.31	7.69	-	195 (100.0)	100.00	-	-	-	252 (100.0)
Total	81.91	17.87	0.22	9068 (100.0)	41.16	57.37	0.90	0.57	12257 (100.0)

Source: Field Survey, 2001
Note: * Quantity in litres per day

Table 4.2.10: Dependence of Sample Households on Selected TWHS (Well) in the Sample Villages, Rajasthan (No. of Households)

Dependence/ Village	Nagana	Godavas
All Purposes	1 (2.4)	5 (11.6)
Not at all	17 (41.5)	12 (27.9)
Drinking only	22 (53.7)	28 (65.1)
Total No. of Households	41	43

Note: Figures in parentheses are proportion to the total number of sample households.

Table 4.2.11: Demand for Water Met by Traditional and Modern Sources, Rajasthan

(Percentages)

State	Village	Source			
		Traditional	Modern	Selected TWHS	All
Rajasthan	Nagana	0.22	81.91*	17.87	100.0
	Godavas	1.47	41.16	57.37	100.0

Source: Field Survey, 2001
Notes: Sources in Nagana: traditional - talav, modern – stand post and selected TWHS – well.
* Water from wells is supplied through stand post

Sources in Godavas: traditional – talav and haveda, modern – stand post and selected TWHS – well.

Table 4.2.12: Respondents' Perception of Quality of Water of Wells in Sample Villages, Rajasthan (No. of Households)

Perception About Quality	Nagana	Godavas
Potable (Good for drinking, cooking and domestic use)	35 (100.0)	30 (69.8)
Non-potable but used for other domestic purposes		13 (30.2)
Used for domestic purposes but not for cooking and drinking		12 (27.9)
Used only for livestock drinking		1 (2.3)

Source: Field Survey, 2001
Note: Figures in parentheses indicate the proportion of sample households

4.2.2 Cost Estimation and Willingness to Pay

Estimates of cost of revival/ modernisation of TWHS and laying of piped water system in the two villages surveyed in Rajasthan is presented in Tables 4.2.13 through 4.2.16. As revealed in Table 4.2.17, in both the villages, a strikingly negligible number of households expressed their willingness to pay for the proposed systems. Moreover, those who agreed to pay the amount indicated by them was a paltry about 2 per cent of their monthly household income (Table 4.2.18). This apparently unusual response could be attributed not only to the high incidence of poverty but also to the fact that these villages still manage to meet much of their water requirement from the village wells even during the difficult summer months. Tables 4.2.19 to 4.2.23 provide information on WTP amounts households were willing to pay during the survey exercise; these data are classified across income and landholding size. Nevertheless, these tables have limited scope of explanation, as the total numbers who were willing to pay was extremely small.

Table 4.2.13: Cost Estimates for Revival of TWHS, Nagana

Particulars	Amount in Rs.
Cost of desilting nadi 10,00,000 cubic feet (Desilting material can be used in strengthening the bank of nadi and includes the improvement of nadi catchment/ channel)	5,66,000
Making approaches and livestock drinking stands	34,000
Total	6,00,000

Table 4.2.14: Cost Estimates for Revival of TWHS, Godavas

Particulars	Amount in Rs.
Cost of desilting nadi Phase I 25,00,000 cubic feet = 70750 cubic metre @ Rs 17.67/ cum	12,50,000
Cost of desilting nadi Phase II (desilted earth will be used for strengthening nadi banks and improvement of nadi channel)	10,00,000
Total	22,50,000

Table 4.2.15: Cost Estimate of Laying Piped System, Nagana

Particulars	Amount in Rs
Laying of pipelines –50mm diameter	1,86,000
Distribution lines for 103 houses and Panchayat Ghar school and dispensary	90,000
Installation of infrastructure for Pumping and Storage	40,000
Total	3,16,000

Table 4.2.16: Cost Estimates of Laying Piped System, Godavas

Particulars	Amount in Rs.
Laying of pipe lines – 50 mm diameter	1,50,000
Installation of infrastructure for storage and boosting of water	2,00,000
New tube well with Pump	1,70,000
Total	5,20,000

Table 4.2.17: Household Level Willingness to Pay for Revival of TWHS and Laying of Piped System, Rajasthan (No. of households)

Village	TWHS			Piped System		Total Number of Sample Households
	Capital Cost	O & M	Labour	Capital Cost	O & M	
Nagana	5 (14.3)	34 (97.1)	34 (97.1)	2 (5.7)	6 (17.1)	41
Godavas	2 (4.7)	43 (100.0)	43 (100.0)	-	-	43

Note: Figures in parentheses are the proportions to the total number of sample households

Table 4.2.18: Proportion of Expenditure on Education, Health and WTP Amounts to the Total Household Income of Sample Households, Rajasthan (Percentages)

Village	Education	Health	WTP
Nagana	6.43	18.65	2.02
Godavas	12.42	9.36	1.52

Table 4.2.19: Frequency Distribution of WTP Amounts in the Sample Villages for Revival of TWHS, Rajasthan

Proportion of Amount	Frequency (%)	Average WTP (Rs.)
Nagana		
Nil	27 (77.1)	-
< 25%	5 (14.3)	300.00
26-50%	1 (2.9)	2000.00
51-75%	-	-
75-99%	-	-
100%	2 (5.7)	5000.00

All Classes	35 (100.0)	385.71
Godavas		
Nil	36 (83.7)	-
< 25%	5 (11.6)	1140.00
26-50%	2 (4.7)	2000.00
51-75%	-	-
75-99%	-	-
100%	-	-
All Classes	43 (100.0)	225.58

Note: Figures in parentheses are the proportions to the total number of sample households

Table 4.2.20: Willingness to Pay for TWHS Across Income Classes, Rajasthan

Income (Rs. Per Month) Range	Proportion of Amount of WTP						
	0	< 25%	26-50%	51-75%	76-99%	100%	All
Nagana							
< 1000	15 (42.9)	3 (8.6)				1 (2.9)	19 (54.4)
1000-4000	12 (34.3)	2 (5.7)	1 (2.9)			1 (2.9)	16 (45.8)
4001-8000							
>8000							
All classes	27 (77.1)	5 (14.3)	1 (2.9)			2 (5.7)	35 (100.0)
Godavas							
< 1000	9 (20.9)	3 (7.0)					12 (27.9)
1000-4000	27 (62.8)	2 (4.7)	2 (4.7)				31 (72.2)
4001-8000							
>8000							
All classes	36 (83.7)	5 (11.6)	2 (4.7)				43 (100.0)

Note: Figures in parentheses are percentages to the total number of sample households in the respective villages.

Table 4.2.21: Willingness to Pay for TWHS Across Landholding Classes, Rajasthan

Landholding classes (in hectares)	Proportion of Amount of WTP						
	0	< 25%	26-50%	51-75%	76-99%	100%	All
Nagana							
<1 ha (Marginal)	17 (56.7)	3 (10.0)	1 (3.3)			1 (3.3)	22 (73.3)
1-2 ha (Small)	2 (6.7)						2 (6.7)
2-10 ha (Medium)	3 (10.0)	2 (6.7)				1 (3.3)	6 (20.0)
>10 ha (Large)							
All classes	22 (73.3)	5 (16.7)	1 (3.3)			2 (6.7)	30* (100.0)
Godavas							
<1 ha (Marginal)	17 (51.5)	4 (12.1)	1 (3.0)				22 (66.6)
1-2 ha (Small)	9 (27.3)		1 (3.0)				10 (30.3)

2-10 ha (Medium)	1 (3.0)						1 (3.0)
>10 ha (Large)							
All classes	27 (81.8)	4 (12.1)	2 (6.1)				33* (100.0)

Note: Figures in parentheses are percentages to the total number of sample households in the respective villages.

* Total Number of Households does not include landless households i.e. 5 in Nagana and 10 in Godavas.

Table 4.2.22: Willingness to Pay for Piped System Across Income Classes, Rajasthan

Income (Rs. Per Month) Range	Proportion of Amount of WTP						
	0	< 25%	26-50%	51-75%	76-99%	100%	All
Nagana							
< 1000	17 (48.6)		1 (2.9)			1 (2.9)	19 (54.4)
1000-4000	13 (37.1)	1 (2.9)	1 (2.9)			1 (2.9)	16 (45.8)
4001-8000							
>8000							
All classes	30 (85.7)	1 (2.9)	1 (2.9)	1 (2.9)		2 (5.7)	35 (100.0)
Godavas							
< 1000	11 (25.6)	1 (2.3)					12 (27.9)
1000-4000	30 (69.8)	1 (2.3)					31 (72.1)
4001-8000							
>8000							
All classes	41 (95.3)	2 (4.7)					43 (100.0)

Note: Figures in parentheses are percentages to the total number of sample households in the respective villages.

Table 4.2.23: Willingness to Pay for Piped System Across Landholding Classes, Rajasthan

Landholding Classes (in hectares)	Proportion of Amount of WTP						
	0	< 25%	26-50%	51-75%	76-99%	100%	All
Nagana							
<1 ha (Marginal)	18 (60.0)	1 (3.3)	1 (3.3)	1 (3.3)		1 (3.3)	22 (73.2)
1-2 ha (Small)	2 (6.7)						2 (6.7)
2-10 ha (Medium)	5 (16.7)					1 (3.3)	6 (20.0)
>10 ha (Large)							
All classes	25 (83.3)	1 (3.3)	1 (3.3)	1 (3.3)		2 (6.7)	30* (100.0)
Godavas							
<1 ha (Marginal)	21 (63.6)	1 (3.0)					22 (66.6)
1-2 ha (Small)	10 (30.3)						10 (30.3)
2-10 ha (Medium)	1 (3.0)						1 (3.0)
>10 ha (Large)							
All classes	32 (97.0)	1 (3.0)					33* (100.0)

Note: Figures in parentheses are percentages to the total number of sample households in the respective villages.

* Total Number of Households does not include landless households i.e. 5 in Nagana and 10 in Godavas.

4.2.3 Factors Affecting Consumption of Water and Willingness to Pay, Rajasthan

Consumption of Water

Table 4.2.24 presents the results of multiple regression analysis, suggesting that the family size (TSNO of sample households in Rajasthan appears to be the significant variable. The per capita consumption of water declines by a factor of 0.51 with a unit increase in family size.

Table 4.2.24: Results of Multiple Regression with Per Capita Consumption of Water (CONWAT) as Dependent Variable, Rajasthan

Independent Variables	Standardized Coefficients	t	Sig.
Constant	-	7.388	0.000
PCINC	-0.038	-0.332	0.741
CASTE	0.126	1.248	0.216
TSNO	-0.513*	-4.359	0.000
TRTIME	-0.166	-1.585	0.117

OWNLAND	0.072	0.692	0.491

Adjusted R Square = 0.270

Computed F Value = 6.708 Significance = 0.000

Degrees of Freedom = 77 (Total)

* Significant at 1 per cent level

Willingness to Pay for Revival of TWHS

Logistic regression was run to identify the variables affecting the household willingness to pay for the revival of TWHS with the same set of independent variables as explained in Chapter 2. However, none of the independent variables was found to be significantly influencing the household willingness to pay (Table 4.2.25).

Table 4.2.25: Results of Logistic Regression with Willingness to Pay for the Revival of TWHS (WTPHS) as the Dependent Variable, Rajasthan

Independent Variable	Standard error	Wald	df	Sig	Exp (B)
PCINC	0.004	0.135	1	0.714	0.999
PCEDUEX	0.002	0.599	1	0.439	0.999
TSNO	0.187	0.005	1	0.941	1.014
CASTE	0.450	0.394	1	0.530	0.754
TRTIME	0.097	0.204	1	0.651	1.045
EDU	0.066	0.047	1	0.828	1.014
PCHUMQ	0.021	0.033	1	0.856	0.996
PCLSQ	0.066	0.145	1	0.703	0.975
Constant	1.996	0.062	1	0.804	0.609

Nagelkerke R square = 0.071
Cox & Snell R Square = 0.043 Significance = 0.961
Degrees of Freedom = 8 (Model)

Chapter 5

Case Study III: Talavs of Kutch, Gujarat

5.1 Selected Talavs in Gujarat

5.1.1 Hydrological and Structural Features of Selected Talavs

Kutch District

Kutch district forms the northwestern part of Gujarat State, a crescent shaped peninsula between the Rann of Kutch and Gulf of Kutch. The district lies between the latitudes 22°44' and 24°41'25" North longitudes 68°03' 46" and 71°54' 47" East. Kutch region consists of the Ranns, a salt incrusted wasteland rising only a few metres above sea level and inundated during monsoon, the hilly region of the Kutch main land and the southern coastal plains. Average annual rainfall of Kutch district is 383 mm (1961-97) and the temperature varies between 25°C to 48°C in summer and 20°C to 5°C in winter season (Map 5.1.1). Rivers which drain the area have deep cut ravines and they are of ephemeral type, carry water only during the period of south-west monsoon for a few days and some carry for a few hours in a day or for a couple of days in a year. Among the north flowing rivers the important one is Khari which covers a course of 51 km and among the south flowing rivers Bhukhi and Kankavati cover a course of 48 km across the Abdasa plain (Map 5.1.2). The general sequence of the rocks obtained in the Kutch district is given in Table 5.1.1. This table indicates the types of rocks and their aquifer characters.

Tera

Tera village is located at a distance of 70 km from Bhuj on Bhuj Naliya road. Naliya is a taluka of Kutch district with its headquarters at Naliya, located 10 km west of Tera village. Tera village falls between Latitude 23°17' North and Longitude 68°56'06" East. Rukmavati River traverses south east to north west and cross village Tera in the north (Figure 5.1.1). The river is ephemeral in nature and flows for few days in monsoon season only (Plate V5.10.C). One dam has been constructed on this river about 15 km upstream of Tera near village Balisara, which has again reduced the monsoon flow (Plate V5.12.M). The area south of Tera village has very sparse vegetation and no signs of ground water development. There are no open wells or tubewells in the area and most of the region is open scrub and wasteland. The reduced level south of Hamirpar is 55 m (amsl) and a 40m contour pass through the area west of Tera village. Reduced level at Tera (canal road crossing) is 47 m. The soil type around Tera village is silt clay loam, the soil profile was inspected at the river section east of village Tera and the soil profile up to riverbed is described as under (Plate V5.11.C):

Table 5.1.1: Sequence of Rock Types Found in Kutch

Depth	Rock Type
0 – 0.20 m	Silt sand
0.20m – .50 m	Silt clay
.50m – 2.00 m	Clay loam
2.00m – 2.30 m	Conglomerate
2.30m – 3.00m	Silt clay stone
3.00 - 3.50	Silt stone
3.50 - > 5.00	Clay stone

Source*: Raju, K. C. B., 1990*

Rainfall of Naliya Taluka for last 10 years is tabulated in Table 5.1.2. Average rainfall for the years 1990-2000 is 370 mm. Water levels of observation open well at Naliya do not show clear fluctuation in water levels due to the salinity effect. Quality of groundwater in the observation well has improved in the year 1992 with a rise in water level of 4.30 m due to above normal rainfall. But in the year 1994 though the rainfall is good there is no appreciable rise in water level and the salinity has also not improved. Similarly in the year 1999 the rainfall is good, the salinity level has improved but there is no rise in water level.

Tera village falls in the geological formations of miocene and pliocene of teritary age. Pliocene rocks of tertiary era are siltstone and clay stones and the miocene rocks are yellow fossiliferous limestone and grey clays. In Naliya, Tera, Mothala area where siltstones and claystones are predominant rock types. These rocks do not make potential geological aquifers. Claystones do not transmit ground water to further depths laterally and vertically downwards due to poor permeability. An aquifer is the strata which stores and transmits ground water. Silt stones and clay stones of pliocene cannot be called as aquifers because clays do have porosity but it does not have the property of permeability and capacity to transmit groundwater.

Runoff from such clay areas is high and the surface water merges into the sea through drains and streams. Cretaceous sandstones are the potential groundwater aquifers where tubewells are drilled for drawing groundwater from white coloured medium to coarse sandstones. Water supply tubewells are drilled in this formation only.

Table 5.1.2: Rainfall and Groundwater Levels, Tera*

Year	Rainfall (mm)	WL		TDS	
		In May (m)	In October (m)	In May (ppm)	In October (ppm)
1991	20	10.20	10.10	2080	1980
1992	720	11.40	7.10	1760	2000
1993	129	8.10	7.80	5400	4240
1994	633	10.30	9.70	4000	4860
1995	360	10.30	7.00	5440	5580
1996	149	9.50	9.50	6420	2380
1997	267	10.60	9.80	2420	2500
1998	346	10.80	10.40	2780	3200
1999	607	8.00	8.70	1660	2310
2000	262	11.00	10.50	3080	3000
2001	236	10.15	9.40	2930	2680

Source: *Gujarat Water Resources Development Corporation, 2002*
*Naliya Observation Well

Tubewells

The potential aquifer of Bhuj sandstone (createaceous) occurs at a distance of about 22 kms from Tera. Tube wells are drilled near Netra village and pipelines are laid from Netra to different villages for water supply purposes. Bhuj sand stone is the only one potential aquifer system in whole of Kutch district and the regional water supply schemes are based on these aquifer formation only. Three tubewells in Netra, supply drinking water to 11 villages including Tera. The supply data is given as under:

Table 5.1.3: Dimensions of Tubewells, Tera*

Details	Dimensions
One tubewell of Netra discharges	500 lpm (litres per minute)
Three tubewells of Netra discharge	1500 lpm
Three tubewells of Netra will give	6,30,000 lpd (litres per day)
11 villages will have a population of	22,000
11 villages will require	10,30,000 lpd
Shortage of water	4,00,000 lpd
Total tubewells needed	6

Present supply status (irregular)	21.81 lpd/s

Source: Field Survey, 2002
*Observation well at Netra

Tera Talavs

There are three rain water storage talavs in Tera village constructed for domestic water supply to the village for washing/ bathing (Plate V5.8.U)and drinking purpose (Plate V5.1.S). These talavs are reservoirs connected with each other in such a way that the overflow of first talavs fills the second talav and overflow of the second talav falls in the third talav. Overflow of the third talav spills over to the river. The talavs are dug from ground level to levels below ground level to depths (-) 6-8m bgl (Figure 5.1.2). The soil, which is obtained on digging, is used for raising embankments on the side.

The Tera talavs consist of eight structures:

1. Intake canal leading to first talav.
2. Inlet structure receiving rainwater and filling Talav1
3. Talav 1 (Chhatasar)
4. Outlet structure from Talav 1 (or inlet to Talav 2)
5. Talav 2 (Sumrasar)
6. Outlet from Talav 2 (or inlet to Talav 3)
7. Talav 3 (Chatasar)
8. Outlet from Talav 3 to the river

Description on individual structures is presented in the following:

Intake Canal

The canal is 3-4 m wide and 1-1.5 m. high on both the sides. The intake canal is about 200 years old and starts from Bhavanipar, passes south of village Dhuphia, Hamirpar and reaches Talav 1 traversing a distance of about 13 km. On way the canal fills the talav of Hamirpar also. Reduced levels on the trace of canal were observed at 60m near Dhuphi and the level at Tera road/ canal junction is 47m, creating a slope of 1:500 in this section. The canal reaches the inlet to first talav near Kirti Stumbh. It is reported by the villagers that one spell of 150mm rainfall at the catchment Bhavanipar is sufficient to fill all the three talavs.

Inlet structure from Canal to Talav 1

The inlet structure receives the gushing rainwater from the canal and fills the first talav. The inlet section (RCC) is 12.50m wide and embankments are raised on both the sides as part of talav 1. Sloping steps are constructed to fill the talav 1. The intake canal is not dug right upto the inlet but the rainwater from the intake canal makes a wide channel near the Kirti Stumbh and enter into talav 1. The embankments of Chhatasar talav are 4 to 5 m high. Chhatasar talav is approximately 8 m deep. Shape of Chhatasar talav is like a horseshoe and it is 130 m long and 120 m wide making the spread area equal to 15600m^2. With a water column of 5 m the talav can store 78000m^3 of water (Plate V5.2.S).

Inlet structure from Talav 1 to Talav 2

The channel to talav 2 is lined on both sides with stone masonry of 6 m depth and 1m wide. The inlet channel is 15 m wide and 4 m deep at the entrance (Plate V5.5.S). After 100 m of its length it takes a turn perpendicular to its transverse and then after a length of 60 m reach the talav 2 (Plate V5.3.S).

Talav 2 (Sumrasar)

Sumrasar is the second talav in the system. This talav is used for drinking water purpose. First and second talavs are separated by an earthen bund of 20 metres widths and 5 metres depth (Plate V5.4.S). All along the periphery of Sumrasar talav there is lining by a limestone slab wall of 1.5 metres width and the limestone slabs are joint firmly together with lime. The stone wall around the talav keeps the structure intact and deposition of clay in the periphery bund works as an impervious barrier to check the impurities. The talav floor could be of hard impervious limestone underlain by the natural clay stone of the area, keeping the talav floor impervious and not mixing with saline ground water. The spread area of the talav, as measured is 6000 m^2.

Table 5.1.4: Volume of Water in the Sumrasar Talav

Date	Water level m	Volume of Water m^3
25/6/2001	2.00	36000 m^3
19/1/2002	4.75	19500 m^3
21/1/2002	5.05	17700 m^3
8/5/2002	6.74	7560 m^3

Source: Field Survey, 2001-2002

Inlet to Talav 3

The overflow from talav 2 is collected in Chatasar Talav (Plate V5.6.S and Plate V5.7.S). Talav-3 is used for livestock drinking only.

Talav 3 (Chatasar)

Chatasar talav is the third talav constructed for use by cattle (Plate V5.9.U). The size of the talav is 15000 m^2 and the talav is 6.00 m deep. The talav is leaky and looses collected water in 7 months.

Outlet from Talav 3 to the River

The overflow from talav 3 passes over the outlet and merges in the river.

Reha Mota

Village Reha Mota is located 22 kms south of Bhuj and can be reached through Bhuj - Anjar road. Reha Mota village falls at latitude 23°8'30" north and longitude 68°45' east (Map 5.1.3). Mathali river traverses north to south and passes east of village, which is named as Bhukhi or Ganga in the south near village Bandru Nana. The river is ephemeral and flows for few days in monsoon only. The area has dendritic drainage pattern beginning from the northern hills and sloping in south easterly direction. Vegetation is sporadic with the growth of acacia trees around the village. The soil type of Reha Mota is sandy, made up from the weathering of cretaceous sandstones prevalent in the area. Soil profile of the village differs as per the land use pattern. A typical soil profile in an agriculture field is described as under

0.00m to 0.30m	Overburden of fine grained sandy soil
0.30m to 1.00m	Medium to grained ferruginous sands
1.00m to 2.50m	White coloured weathered sandstone
2.50m - > 5.00m	Sandstone

Reha Mota village falls in a typical cretaceous sandstone country of Kutch. A typical geological section shows alternate bands of white sandstone and shales seen in a dam section north west of village Reha (Figure 5.1.3). Cretaceous sandstones are potential aquifers of Kutch transmitting groundwater in the sub stratum. Cretaceous sandstone rocks of this area possess primary porosity and permeability and they transmit groundwater laterally and vertically. The typical design of a tubewell is given in Table 5.1.5.

Table 5.1.5: Dimensions of Tubewell, Reha Mota

Details	Dimensions
Depth of tubewell	150 m
Aquifer type	Sandstone
Water level in tubewells	60 m
Discharge from tubewells	500 lpm
Pipes in tubewells around Reha Mota	6 m casing and uncased further
Number of tubewells in Reha Mota	50 (appx.)

Source: Field Survey, 2002

Waste land areas around Reha Mota village are being converted into tubewell irrigated area. Water level of one piezometer of 90m deep in Bhuj sandstone is given in Table 5.1.6.

The rate of fall in water levels of tubewells in Kutch varies from 1 to 5 m. Heavy withdrawal of groundwater leads to such decline in groundwater levels. The values in Table 5.1.6 indicate that the water level has fallen 3.60 m in four years.

Table 5.1.6: Rainfall and Groundwater Levels, Bhuj

Year	Rainfall (mm)	Water Level (m)
1990	201	
1991	31	
1992	597	
1993	106	
1994	800	
1995	152	
1996	87	
1997	314	
1998	416	58.60
1999	319	
2000	290	
2001	262	
2002		62.20

Source: *Socio Economic Review: Gujarat State, 2000-2001*

Tubewell

One tubewell located at 1 km away from the village on Reha Bharapar road supplies drinking water to Reha Mota and Reha Nana. The depth of tubewell is 120 m deep and it is pumped for seven hours a day depending on the power supply.

Table 5.1.7: Dimensions of the Tubewell, Reha Mota

Details	Dimensions
Depth of tubewell	150 m
Aquifer type	Sandstone
Water level in tubewells	60 m
Discharge from tubewells	500 lpm
One tubewell gives in 7 hours	2,10,000 lpd
Quality of tubewell water	Potable

Source: Field Survey, 2002

Reha Talav

One talav has been constructed in the western side of the village which receives rainwater from a channel dug for a distance of 2.75 kms and receiving rainwater from series of check dam and talav system. At a distance of 3 kms north west of the village Reha Mota there is one check dam built on a local drainage, Overflow from this dam flow in south westerly direction and meets one diversion weir built to divert the flow towards south eastern direction (Figure 5.1.4). The diverted flow of rainwater moves in the south easterly direction, through a humanmade old channel, dug through sandstone and fills one talav made specially to arrest the silt from the flowing rainwater. Water overflowing from this talav travels through the continuous channel and fills the Reha talav. This talav is 100 m wide and 150m long and 6 m deep in the middle. The capacity of Reha Talav is 40,000 m^3. The incoming rainwater passes through silting platforms built in the talav itself. Overflow from the Reha talav fills the second talav neaby. This second talav is used for washing and bathing. Hydrological details of the talav are given as under:

Table 5.1.8: Dimensions of Talav, Reha Mota

Details	Dimensions
Area	15000 m^2
Depth of live storage	4 m
Capacity of Talav considering the silting basins	40,000 m^3
Water level on June 26th 2001	2.00 m
Talav filled on June 26th 2001	30,000 m^3
Water level in Talav on 23rd Feb. 2002	4.50 m
Water used up in 8 months	25000 m^3
Domestic consumption for seven months	6300 m^3
Water level on 2nd May	5.70 m
Condition of talav on 2nd May	Dry

Source: Field Survey, 2002

Intake Channel

The man made intake channel is 3 to 4 m wide and 1 to 1.5m deep dug through the sandstone country traversing a distance of 2.75 km. The channel starts from the diversion weir .25 kms south of the first check dam. This is an old traditional channel which carries the rain water to the Reha talav. This channel has got silted up 100 m before entering the Reha talav.

Talav 2

This is a small talav built to arrest silt and sand coming with rainwater.

Check Dam

The check dam which receives the first spell of rainwater in the system has been built by irrigation department of Government of Gujarat. The overflow water from this check dam spills over and enters the main stream.

Diversion Weir

This is a small raised wall .60 m high and 20 metres long to divert the overflowing river water from the check dam to the man made channel constructed to fill the talav 2.

Small Reha Talav

The overflow of Reha talav fills the washing talav situated 100 m south of Reha main Talav. The area of this talav is 10000m^2 and the capacity is 15000m^3

5.1.2 Quality of Water

Tera

Table 5.1.9 showing the quality of groundwater of open wells shows total dissolved salts is higher than 3000 ppm. High concentration of Sodium Chloride is also making the water saline. For drinking purposes the limit of TDS is 1500 parts per million in Indian conditions and in international standards only TDS of 1000 ppm is allowed. Moreover, the open well water is not suitable for domestic use due to high salinity. Layers of clay stones at shallow depths in the open wells of Tera do not transmit groundwater and due to inertia condition, the water stored turns saline.

Table 5.1.9: Chemical Analysis of Water Samples of Wells, Tera

Sample No.	1	2
Well/Bore	Open Well of Maharaj	Open Well of Mistry
Village	Tera	Tera
Tehsil	Naliya	Naliya
District	Kutch	Kutch
Depth	12.50m	13.00m
SWL	11.20m	11.60m
EC mmhos/cm	5300	6590
PH	7.7	7.7
TDS ppm	3010	3760
Calcium (Ca)	185/9.25	180/9.00
Magnesium (Mg)	189/15.75	237/19.75
Sodium (Na)	640/27.82	851/37.00
Potassium (K)	10/0.26	6/0.15
Carbonate (CO_3)	Nil	Nil
Bicarbonate (HCO_3)	232/ 3.80	342/ 5.60
Sulphate (SO_4)	15/ 0.31	19/ 0.40
Chloride (Cl)	1736/ 48.90	2128/ 59.94
Remarks	*Not suitable for use*	*Not suitable for use*

The talav water from Tera was also tested for chemical composition and bacterial concentrations. Table 5.1.10 presents the results of chemical test. The talav water being the rainwater is less saline and has low amounts of TDS. However, the bacteriological tests revealed that the talav water is highly contaminated with the presence of coliform bacteria. The water needs to be treated with chlorine or bleaching powder (Table 5.1.11).

Table 5.1.10: Chemical Analysis of Water Sample of Talav, Tera

Sample No.	1
Well/Bore	Tera Talav
Village	Tera
Tehsil	Naliya
District	Kutch
Odour	Unobjectionable
Turbidity NTU	4
PH	8.46
TDS mg/l	150
Calcium (Ca) mg/l	14
Magnesium (Mg) mg/l	8
Chlorides (Cl)	24
Sulphate (SO_4)	7
Nitrate	Nil
Fluoride	0.16
Alkalinity	84
Remarks	*Potable*

Table 5.1.11: Bacteriological Analysis of Water Sample of Talav, Tera

Particulars	MPN of Coliform per 100 ml of sample	MPN of faecal coliforms per 100 ml of sample
Tera village talav	> = 1600	220
Remarks	*Unfit for potable use*	

Reha Mota

One tubewell located at 1 km away from the village on Reha - Bharapar road supplies drinking water to Reha Mota and Reha Nana. The depth of tubewell is 120 m deep and it is pumped for seven hours a day depending on the power supply. Water samples were collected from two tubewells and the analysis results are given in Table 5.1.12. Chemical test results show that the total dissolved salts in water supply tubewell of Reha Mota is 1520 ppm, caused by high magnesium and sodium chlorides, whereas maximum permissible limit is 1500 ppm in Indian conditions.

Water supply department has to treat this water before supply. One more water supply tubewell is being constructed near Reha Mota village on Bharapar road at a distance of 2 km. The chemical analysis of second water sample of a farmer's tubewell located at a distance of 1.5 km from Reha Mota is fit for irrigation and domestic purposes.

Table 5.1.12: Chemical Analysis of Water Samples of Tubewells, Reha Mota

Sample No.	1	2
Well/Bore	Reha Mota Ws Tubewell	Reha Mota Irri. Tubewell
Village	Reha Mota	Reha Mota
Tehsil	Bhuj	Bhuj
District	Kutch	Kutch
Depth	120 m	130 m
SWL	60 m	58 m
EC mmhos/cm	2570	1480
PH	7.41	7.2
TDS	1520	930
Calcium (Ca)	145/ 7.25	125/ 6.25
Magnesium (Mg)	99/ 8.25	69/ 5.75
Sodium (Na)	230/ 10.00	64/ 2.78
Potassium	4/ 0.10	2/ 0.05
Carbonate (CO_3)	Nil	Nil
Bicarbonate (HCO_3)	256/ 4.20	244/ 3.60
Sulphate (SO_4)	106/ 2.21	115/ 2.40
Chloride (Cl)	680/ 19.15	312/ 8.79
Remarks	*Suitable after treatment*	*Suitable for use*

Table 5.1.13: Bacteriological Analysis of Water Sample of Talav, Reha Mota

Sample of	MPN of Coliform per 100 ml of sample	MPN of faecal Coliforms per 100 ml of sample
Reha village talav	> = 1600	> = 1600
Remarks	*Unfit for potable use*	

The results of bacteriological and chemical analysis of water samples from Reha Mota Talav are shown in Tables 5.1.12 and 5.1.13. The bacteriological analysis of Reha Talav water samples indicate concentration (in mpn) of coliform bacteria is greater than 1600/100 ml indicating that the water is unfit for potable use. The permissible standard limit for coliform bacteria is 50/ 100ml. Talav water will need treatment before human consumption. Chemical quality of Reha Talav water is fit for use as shown in Table 5.1.14

Table 5.1.14: Chemical Analysis of Water Sample of Talav, Reha Mota

Sample No.	2
Well/Bore	Reha Talav
Village	Reha
Tehsil	Bhuj
District	Kutch
Odour	Unobjectionable
Turbidity NTU	240
PH	8.18
Total hardness as $CaCO_3$ mg/l	272
TDS mg/l	520
Calcium (Ca) mg/l	46
Magnesium (Mg) mg/l	37
Chlorides	116
Sulphate (SO_4)	58
Nitrate	0.34
Fluoride	0.25
Alkalinity as ($CaCO_3$) mg/l	152
Opinion	*Fit for potable use*

5.2 Socio-Economic Characteristics of Sample Villages

These sample villages in Kutch, are relatively better endowed with basic amenities including access to health communication and transport facilities (Table 5.2.1). As may be seen from Tables 5.2.2 and 5.2.3 the main occupation of the households in both the villages relate to agriculture and dairying. In terms of social groups, whereas in Tera in about 52 per cent of the households belong to OBC, ST and SC categories, in Reha Mota the same account for 65 per cent of the total sample households (Table 5.2.4). Although the average landholding size is above 1hectare, the average annual income of the households is in fact very low. About 90 per cent of the sample households had an average monthly income below Rs 4000. As the agriculture here is essentially rainfed and the soil salinity is high, the average yield is generally low (Tables 5.2.5 and 5.2.6).

Table 5.2.1: Basic Amenities in the Sample Villages, Gujarat

Amenities	Tera	Reha Mota
Roads	Pucca (to SH, 1km)	Pucca (to SH, 1km)
Bus Services	Pvt. and Pub. frequently	Pvt. and Pub. frequently
Railway Station	12 km	10 km

Schools	Primary (2) Secondary (1)	Primary (1)
Medical Facilities	Dispensary	Sub-centre
Post Office	Branch PO	Branch PO
Telephone	PCO, Pvt.	PCO, Pvt.
Market	APMC (12 km)	APMC (10 km)
Community Gathering Places	Chowk	School and Temple

Source: Field Survey, 2001

Table 5.2.2: Population Profile of Sample Villages, Gujarat

Particulars	Tera	Reha Mota
Population	2394 (53.13)	1397 (51.61)
Population (0-6)	412 (49.03)	248 (46.77)
Scheduled Castes	44 (40.91)	150 (43.33)
Scheduled Tribes	283 (45.23)	59 (44.07)
Literates	1174 (43.61)	605 (43.47)

Source: *District Census Handbook, Kutch, 1991*

Note: Figures in parentheses indicate percentages of female population.

Table 5.2.3: Distribution of Workers in the Sample Villages, Gujarat

Particulars	Tera		Reha Mota	
	Males	Females	Males	Females
Main Workers	628	322	312	89
Cultivators	195	122	63	16
Agricultural Labourers	183	129	78	27
Livestock & Allied Activities	20	-	16	-
Mining & Quarrying	-	-	1	-
Household Industry	50	47	61	31
Construction	11	1	28	1
Trade and Commerce	69	1	19	-
Transport Storage and Communication	14	-	16	1
Other Services	86	22	30	13
Marginal Workers	1	175	49	76
Non workers	493	775	315	556

Source: *District Census Handbook, Kutch, 1991*

Table 5.2.4: Caste and Family Size of Sample Households in the Sample Villages, Gujarat

Particulars	Tera	Reha Mota
Number of Households	50	60
Population	243	329
Family Size	4.9	5.5
Caste:		

SC	5 (10.0)	7 (11.7)
ST	7 (14.0)	7 (11.7)
OBC	14 (28.0)	25 (41.7)
General	24 (48.0)	21 (35.0)

Source: Field Survey, 2001

Note: Figures in brackets indicate proportions to the total number of sample households in the village

Table 5.2.5: Income Classes of Sample Households, Gujarat

Village	Income Groups (Monthly Income in Rupees)				
	< 1000	1000-4000	4001-8000	> 8000	All
Tera	13 (26.0)	32 (64.0)	5 (10.0)	-	50 (100.0)
Reha Mota	9 (15.0)	47 (78.3)	4 (6.7)	-	60 (100.0)

Source: Field Survey, 2001

Note: Figures in brackets indicate proportions to the total number of sample households in the village

Table 5.2.6: Landholding Status of the Sample Households, Gujarat

Landholding	Villages (No. of Households)	
	Tera	Reha Mota
Average Landholding (in hectares)	1.05	0.20
<1 ha (Marginal)	7	5
1-2 ha (Small)	11	2
2-10 ha (Medium)	8	1
>10 ha (Large)	-	-
Landless	24	52

Source: Field Survey, 2001

5.2.1 Consumption Pattern and Dependence on TWHS

Like in most of the villages in Kutch, both Tera and Reha Mota suffer from deficiency in water for domestic use (Table 5.2.7). However, in both the villages the dependence on the traditional sources is notable; in Tera it is 100 per cent as the piped water supply was reported to be extremely unreliable, in Reha Mota about 70 per cent of water need is met by the traditional sources. Unlike Tera, in Reha Mota piped water supply is fairly reliable largely because of ample groundwater resources (Table 5.2.8 through 5.2.11). Nevertheless in both the villages opinion varied regarding the quality of water in the TWHS (Table 5.2.12).

Table 5.2.7: Demand Pattern for Domestic Water Use in Sample Villages, Gujarat

(litres per day)

Purpose	Tera		Reha Mota	
	Total Qty Used	Per Capita Qty Used	Total Qty Used	Per Capita Qty Used
Drinking Human	2775	11.42	3975	12.08
Cooking	1105	4.55	1175	3.57
Bathing Males	1460	17.38	2010	18.79
Bathing Females	1380	18.65	1990	18.09
Bathing Children	1295	15.24	1660	14.82
Washing Clothes	1980	8.15	2495	7.58
Washing Utensils	1305	5.27	1410	4.29
Latrine Males	180	0.74	190	0.58
Drinking Animals	10	0.06		
All Purposes	11450	28.00	14905	34.91
Standard Quantity (Human)	13120		16640	
Standard Quantity (Livestock)	4980		2990	
Deficiency (Human)	1680 (12.81)		1735 (10.43)	
Deficiency (Livestock)	4970 (99.80)		2990 (100.00)	
Total Deficiency	6650 (36.74)		4725 (24.07)	

Source: Field Survey, 2001

Notes: Standard quantity for human consumption is based on the criterion of 40 lpcd (litres per capita per day)

Standard quantity for livestock (cattle at 30 lpcd and sheep & goat at 10 lpcd)

Total deficiency includes deficiency for human and livestock consumption plus the actual quantity of water used for animal washing.

Figures in parentheses are the percentage of deficiency towards standard quantity required.

Table 5.2.8: Percentage Distribution of Water Use by Source and Purpose in Gujarat

(Percentages)

Particulars/ Source	Tera		Reha Mota		
	Talav	Well	Talav	Tap	Well
Drinking Human	24.51	15.15	24.44	31.03	25.69
Cooking	9.49	15.15	8.64	5.48	16.51
Bathing Males	12.72	13.64	11.51	17.14	14.68
Bathing Females	12.23	6.06	12.67	14.91	11.01
Bathing Children	11.38	9.09	12.99	7.30	13.76
Washing Clothes	17.00	27.27	19.19	12.68	11.01
Washing Utensils	11.33	13.64	9.81	9.03	7.34
Latrine	1.26		0.74	2.43	
Drinking Animals	0.09				
Washing Animals					
Total*	11120 (100.0)	330 (100.0)	9430 (100.0)	4930 (100.0)	545 (100.0)

Source: Field Survey, 2001

Note: * Quantity in litres per day

Table 5.2.9: Purpose-wise Proportion of Demand for Water Met by Different Sources in Sample Villages, Gujarat

(Percentages)

Purpose/ Source	Tera			Reha Mota			
	Talav	Well	All*	Talav	Private Tap	Well	All*
Drinking Human	98.20	1.80	2775 (100.0)	57.99	38.49	3.52	3975 (100.0)
Cooking	95.48	4.52	1105 (100.0)	69.36	22.98	7.66	1175 (100.0)
Bathing Males	96.42	3.08	1460 (100.0)	53.98	42.04	3.98	2010 (100.0)
Bathing Females	98.55	1.45	1380 (100.0)	60.05	36.93	3.02	1990 (100.0)
Bathing Children	97.68	2.32	1295 (100.0)	73.80	21.69	4.52	1660 (100.0)
Washing Clothes	95.45	4.55	1980 (100.0)	72.55	25.05	2.40	2495 (100.0)
Washing Utensils	96.55	3.45	1305 (100.0)	65.60	31.56	2.84	1410 (100.0)
Latrine	100.00	-	140 (100.0)	36.84	63.16	-	190 (100.0)
Drinking Animals	100.00	-	10 (100.0)	-	-	-	-
Washing Animals	-	-	-	-	-	-	-
Total	97.12	2.88	11450 (100.0)	63.27	33.08	3.66	14905 (100.0)

Source: Field Survey, 2001
Note: * Quantity in litres per day

Table 5.2.10: Dependence of Sample Households on Selected TWHS (Talav) in the Sample Villages, Gujarat

(No. of Households)

Dependence/ Village	Tera	Reha Mota
All Purposes	48 (96.0)	33 (33.0)
Not at all	-	12 (20.0)
Drinking only	49 (98.0)	34 (56.7)
Total No. of Households	50	60

Note: Figures in parentheses are proportion to the total number of sample households.

Table 5.2.11: Demand for Water Met by Traditional and Modern Sources, Gujarat

(Percentages)

Village	Source			
	Traditional	Modern	Selected TWHS	All
Tera	2.88	Highly Unreliable	97.12	100.0
Reha Mota	3.66	33.08	63.27	100.0

Source: Field Survey, 2001
Notes: Sources in Tera: traditional - wells, modern – none and selected TWHS – Talav.

Sources in Reha Mota: traditional – wells, modern – private taps and selected TWHS – Talav.

Table 5.2.12: Respondents' Perception of Quality of Water of Talavs in Sample Villages, Gujarat (No. of Households)

Perception About Quality	Tera	Reha Mota
Potable (Good for drinking, cooking and domestic use)	31 (70.5)	22 (43.1)
Non-potable but used for other domestic purposes		11 (21.6)
Used for domestic purposes but not for cooking and drinking		11 (21.6)
Non-potable and Unsuitable for any domestic purposes	13 (29.5)	18 (35.3)
Used but may cause diseases	12 (27.3)	18 (35.3)
Unsuitable for any domestic purpose	1 (2.3)	

Source: Field Survey, 2001

Note: Figures in brackets indicate proportions to the total number of sample households in the village

5.2.2 Cost Estimation and Willingness to Pay

As per the engineering and hydrgeological surveys there existed much scope for the revival/ modernisation of talavs in both the villages. Tables 5.2.13 and 5.2.14 provide the cost estimates for the interventions required. Also estimates were prepared for laying of piped water system so as to provide household tap connections (Tables 5.2.15 and 5.2.16). The responses to questions on willingness to pay for both the facilities varied distinctly across the villages. In Tera the enthusiasm for the revival of the talav was very high reflecting their strong dependence on talavs and lack of confidence in the reliability of the piped water supply. Contrarily, the respondents in Reha Mota relied heavily upon the piped water system and would not prefer to consider paying for the revival of the talavs, despite their limited dependence on the latter (Tables 5.2.17). Even the amount of cost the respondents in both the villages were willing to pay formed only a meagre less than 4 per cent of their monthly income (Table 5.2.18). For those who were willing to pay for the facilities proposed, the amounts agreed upon have been classified across income class and landholding size in Tables 5.2.19 through 5.2.23.

Table 5.2.13: Cost Estimates for Revival of TWHS, Tera

Particulars	Amount (Rs.)
Cost of Desilting the Talav	5,80,000
Cost of Desilting/ Cleaning of the Channel (Main Canal)	8,30,000
Repair/ Replacement of the Walls and Steps	1,65,000
Slit Traps with wire mesh in the Upper Catchment	85,000
Sub-Total	16,60,000
Add 20%	3,32,000
Total	19,92,000

Table 5.2.14: Cost Estimates for Revival of TWHS, Reha Mota

Particulars	Amount (Rs.)
Cost of Desilting the Talav	1,37,000
Cost of Desilting/ Cleaning of the Channel (Main Canal)	1,95,000
Repair/ Replacement of the Walls and Steps	40,000
Slit Traps with wire mesh in the Upper Catchment	20,000
Sub- Total	3,92,000
Cost of Construction of new Walls and Steps	6,33,000
Sub-Total	10,25,000
Add 20%	2,50,000
Total	12,30,000

Table 5.2.15: Cost Estimates for Laying Piped System, Tera

Particulars	Amount (Rs.)
Tubewell Digging	8,00,000
Laying Pipelines	12,00,000
Taps and pipelines within village	9,22,500
Elevated Storage Reservoir	6,40,000
Total	35,62,500

Table 5.2.16: Cost Estimates for Laying of Piped System, Reha Mota

Particulars	Amount (Rs.)
Elevated storage Reservoir	60,000
Pipelines and Taps within the village	60,000
Total	1,20,000

Table 5.2.17: Household Level Willingness to Pay for Revival of TWHS and Laying of Piped System, Gujarat (No. of households)

Village	TWHS			Piped System		Number of Sample Households
	Capital Cost	O & M	Labour	Capital Cost	O & M	

Tera	34 (77.3)	41 (93.2)	34 (77.3)	8 (18.2)	32 (72.7)	50
Reha Mota	6 (11.8)	46 (90.2)	38 (74.5)	4 (7.8)	7 (13.7)	60

Note: Figures in brackets indicate proportions to the total number of sample households in the village

Table 5.2.18: Proportion of Expenditure on WTP Amounts to the Total Household Income of Sample Households, Gujarat

(Percentages)

Village	WTP
Tera	3.98
Reha Mota	2.40

Table 5.2.19: Frequency Distribution of WTP amounts in the Sample Villages for Revival of TWHS, Gujarat

Proportion of Amount	Frequency (%)	Average WTP (Rs.)
Tera		
Nil	11 (25.0)	-
< 25%	17 (38.6)	235.88
26-50%	5 (11.4)	1120.00
51-75%	1 (2.3)	2000.00
75-99%		
100%	10 (22.7)	3500.00
All Classes	44 (100.0)	1059.32
Reha Mota		
Nil	21 (41.2)	-
< 25%	2 (3.9)	
26-50%	5 (9.8)	
51-75%	2 (3.9)	
75-99%		
100%	21 (41.2)	
All Classes	51 (100.0)	669.61

Note: Figures in brackets indicate proportions to the total number of sample households in the village

Table 5.2.20: Willingness to Pay for TWHS Across Income Classes, Gujarat

Income (Rs. Per Month) Range	Proportion of Amount of WTP						
	0	< 25%	26-50%	51-75%	76-99%	100%	All
Tera							
< 1000	2 (4.5)	7 (15.9)	1 (2.3)			2 (4.5)	12 (27.2)
1000-4000	9 (20.5)	10 (22.7)	4 (9.1)	1 (2.3)		4 (9.1)	28 (63.6)
4001-8000						4 (9.1)	4 (9.1)
>8000							
All classes	11 (25.0)	17 (38.6)	5 (11.4)	1 (2.3)		10 (22.7)	44 (100.0)
Reha Mota							

< 1000	1 (2.0)		2 (3.9)			4 (7.8)	7 (13.7)
1000-4000	20 (39.2)	1 (2.0)	2 (3.9)	2 (3.9)		17 (33.3)	42 (82.4)
4001-8000		1 (2.0)	1 (2.0)				2 (4.0)
>8000							
All classes	21 (41.2)	2 (3.9)	5 (9.8)	2 (3.9)		21 (41.2)	51 (100.0)

Note: Figures in parentheses are percentages to the total number of sample households in the respective villages.

Table 5.2.21: Willingness to Pay for TWHS Across Landholding Classes, Gujarat

Landholding classes (in hectares)	Proportion of Amount of WTP						
	0	< 25%	26-50%	51-75%	76-99%	100%	All
Tera							
<1 ha (Marginal)	2 (8.7)	1 (4.3)	2 (8.7)			1 (4.3)	6 (26.1)
1-2 ha (Small)	1 (4.3)	7 (30.4)	1 (4.3)				9 (39.1)
2-10 ha (Medium)	1 (4.3)	4 (17.4)	1 (4.3)			2 (8.7)	8 (34.8)
>10 ha (Large)							
All classes	4 (17.4)	12 (52.2)	4 (17.4)			3 (13.0)	23*(100.0)
Reha Mota							
<1 ha (Marginal)	2 (33.3)						2 (33.3)
1-2 ha (Small)				1 (16.7)		2 (33.3)	3 (50.0)
2-10 ha (Medium)	1 (16.7)						1 (16.7)
>10 ha (Large)							
All classes	3 (50.0)			1 (16.7)		2 (33.3)	6*(100.0)

Note: Figures in parentheses are percentages to the total number of sample households in the respective villages.

* Total Number of Households does not include landless households i.e. 21 in Tera and 45 in Reha Mota village.

Table 5.2.22: Willingness to Pay for Piped System Across Income Classes, Gujarat

Income (Rs. Per Month) Range	Proportion of Amount of WTP						
	0	< 25%	26-50%	51-75%	76-99%	100%	All
Tera							
< 1000	2 (4.5)	8 (18.2)	1 (2.3)			1 (2.3)	12 (27.2)
1000-4000	8 (18.2)	11 (25.0)	4 (9.1)			5 (11.4)	28 (63.6)
4001-8000				1 (2.3)	1 (2.3)	2 (4.5)	4 (9.1)
>8000							
All classes	10 (22.7)	19 (43.2)	5 (11.4)	1 (2.3)	1 (2.3)	8 (18.2)	44 (100.0)
Reha Mota							
< 1000	5 (9.8)					2 (3.9)	7 (13.7)

1000-4000	38 (74.5)		2 (3.9)			2 (3.9)	42 (82.4)
4001-8000	2 (3.9)						2 (3.9)
>8000							
All classes	45 (88.2)		2 (3.9)			4 (7.8)	51 (100.0)

Note: Figures in parentheses are percentages to the total number of sample households in the respective villages.

Table 5.2.23: Willingness to Pay for Piped System Across Landholding Classes, Gujarat

Landholding classes (in hectares)	Proportion of Amount of WTP						
	0	< 25%	26-50%	51-75%	76-99%	100%	All
Tera							
<1 ha (Marginal)	2 (8.7)	3 (13.0)				1 (4.3)	6 (26.1)
1-2 ha (Small)	3 (13.0)	5 (21.7)	1 (4.3)				9 (39.1)
2-10 ha (Medium)	1 (4.3)	2 (8.7)	1 (4.3)		1 (4.3)	3 (13.0)	8 (34.8)
>10 ha (Large)							
All classes	6 (26.1)	10 (43.5)	2 (8.7)		1 (4.3)	4 (17.4)	23 (100.0)
Reha Mota							
<1 ha (Marginal)	2 (33.3)						2 (33.3)
1-2 ha (Small)	3 (50.0)						3 (50.0)
2-10 ha (Medium)	1 (16.7)						1 (16.7)
>10 ha (Large)							
All classes	6 (100.0)						6 (100.0)

Note: Figures in parentheses are percentages to the total number of sample households in the respective villages.

* Total Number of Households does not include landless households i.e. 21 in Tera and 45 in Reha Mota village.

5.2.3 Factors Affecting Consumption of Water and Willingness to Pay, Gujarat

Consumption of Water

Multiple Regression analysis was also attempted for the sample data from Gujarat. Of the set of independent variables as mentioned in Chapter 2, family size of the sample households (TSNO) in the state was found to be significantly affecting the per capita consumption of water. As is evident from the Table 5.2.24, the per capita consumption of water declined by a factor of 0.7 with a unit increase in the family size.

Table 5.2.24: Results of Multiple Regression with Per Capita Consumption of Water (CONWAT) as Dependent Variable, Gujarat

Independent Variables	Standardized Coefficients	t	Sig.
Constant	-	20.994	0.000
PCINC	0.077	0.947	0.346
CASTE	-0.115	-1.499	0.137
TSNO	-0.702*	-8.396	0.000
TRTIME	0.044	0.531	0.597
OWNLAND	0.065	0.882	0.380

Adjusted R Square = 0.533
Computed F Value = 22.4039 Significance = 0.000
Degrees of Freedom = 94 (Total)
* Significant at 1 per cent level

Willingness to Pay for Revival of TWHS

The logistic regression was also attempted to identify the factors affecting the willingness to pay for the revival of TWHS i.e. talavs in Gujarat. The independent variables per capita consumption of water (PCHUMQ) and the caste of the household (CASTE) turned out to be significantly influencing the household's willingness to pay for the revival of TWHS. Logistic regression results for Gujarat state are given in Table 5.2.25.

Table 5.2.25: Results of Logistic Regression with Willingness to Pay for the Revival of TWHS (WTPHS) as Dependent Variable, Gujarat

Independent Variable	Standard error	Wald	df	Sig	Exp (B)
PCINC	0.001	1.704	1	0.192	1.002
TSNO	0.175	0.588	1	0.443	1.144
CASTE	0.503	12.111	1	0.001	0.174*
TRTIME	0.078	0.048	1	0.826	1.017
EDU	0.080	2.681	1	0.102	1.141
PCHUMQ	0.020	5.697	1	0.017	1.049**
PCLSQ	0.743	0.015	1	0.901	1.096
Constant	1.975	1.734	1	0.188	13.480

Nagelkerke R square = 0.466
Cox & Snell R Square = 0.336 Significance = 0.000
Degrees of Freedom = 7 (Model)

* Significant at 1 per cent level
** Significant at 5 per cent level

Chapter 6

Discussion and Recommendations

6.1 Water Scarcity in Arid Western India: Potential and Limits of TWHS

The impending crisis of scarcity of potable water, even in high rainfall zones, has been emerging as an issue of serious concern, nationwide. That it is no longer feasible to meet all the domestic water needs through perpetual and excessive withdrawal of groundwater is fairly well established by now. In India, whereas mechanisms to ensure prevention of overexploitation of groundwater by variety of competing users (including agriculturists, industrial units and urban settlers) continues to remain in the arena of policy debate, alternative ways and means to meet the growing demand for potable water from the rural sector have come under urgent consideration. This is particularly so as the state-run piped water schemes have left much to be desired in terms of reliability, adequacy and sustainability of supply in rural India.

The relatively recent reorientation in rural water supply, as part of the overall sector reform initiatives, emphasising user financing and local management has also been facing a number of constraints. The most notable of these hurdles concerns the inadequate or no recovery from the very poor rural households. Despite the soundness of the 'efficiency' argument, payment for capital expenditure by individual households in poverty remains a complex issue to tackle.

With this backdrop, the present study focuses on the potential of revival and modernization of traditional water harvesting systems and addresses the vital problematique of ensuring sustainable availability of potable water in rural households through exploring alternative means. It is important to recognize that much of the 'enthusiasm' generated by the decade-and-a-half-old resurgence of interest in TWHS as remarkable alternatives in solving rural water crisis, needs to be validated against their actual potential. This is important as TWHS, by collecting and storing surface run-off and rainwater, represent excellent options in *not* drawing upon the valuable groundwater available beyond the rechargeable limit.

While TWHS are highlighted as the embodiment of evolved techniques based upon knowledge about local environmental and socio-cultural specificities, a large number of them can no longer cater to the total demand for water in the given village whose population kept growing. Further, barring a few, in many cases the traditional form of community-based management of the structures has been a matter of the past. Gross neglect of these CPRs can be evidenced through the existence of damaged structures, polluting the water and even forcible possession by vested interests for private purposes.

Despite the indifference meted out to these age-old structures in many regions, especially when attention centered around the solution that was expected to come about through the modern piped water system, TWHS continue to function in numerous villages of India and if not fully, these sources fulfill demand for water for domestic use partially, particularly during the summer months.

In view of the rather limited and sketchy literature available on TWHS (meant mainly for drinking water purpose) and the growing need to appreciate their environmental and economic performance this study concentrated on three distinct TWHS as extensively found in the Thar Desert and Central Uplands Regions. The systems studied are bavdis in western Madhya Pradesh, wells in western Rajasthan and talavs in Kutch region of Gujarat.

Three distinct approaches were followed:

(a) Hydrogeological and engineering surveys were undertaken to understand the functional dynamics of the systems. These also included exploring possible technical interventions and modifications needed to improve the existing structures so as to enhance the availability of water. Estimates of cost of revival/modernization of TWHS were arrived at following these surveys and consultation with locally informed people, NGOs and concerned engineers and hydrologists in the local state/ taluka department offices. Similarly, estimates of capital expenditure and O&M for installing piped water network in the village, so as to provide tap connection to every household, were also prepared.

(b) In order, to elicit information on demographic, socio-economic variables of the inhabitants and availability of infrastructural facilities, village and household level surveys were conducted. Special care was taken to obtain as much detailed data as possible on water related issues, such as, sources, pattern of use, time taken and distance covered to fetch water and perception about quality. The household and village level structured surveys were supplemented by fairly well attended focus group discussions, oriented in a manner to understand diverse views as expressed freely by the participants. The FGDs dealt primarily with the ticklish issues of community ownership and management of the existing TWHS.

(c) The third but vital approach followed in the analysis related to the valuation of popular willingness to pay for provision of facilities of water through improved TWHS and supplying water through household level tap connections. These exercises in ascertaining households WTP from possible water supply devices, proposed through the creation of a hypothetical market scenario, provided the most interesting clues regarding popular perception about the essentially of TWHS and/or modern piped water supply and their readiness to pay from either or both of these systems. The personal of a slightly modified CVM, essentially by introducing options of mode of payment, was to settle for the most realistic amount that a specific household was ready to spare.

6.1.1 Prospects of TWHS in Thar and Central Highlands: Note on Status

Drawing upon available documentation on TWHS and extensive field surveys in the broad ecological zones of Thar Desert and Central Highlands, it is obvious that TWHS not only vary substantially in terms of technology and management, but also their functioning depends so crucially on local discrete environment.

It was established through extensive field surveys in the different parts of the Thar and Central Highlands geographical regions, that there exist numerous traditional systems of harvesting water. However, most of these systems are lying defunct due to their inadequacy in catering to the water needs of the ever-growing population or have become victim to the negligence in maintenance by the local communities. An exhaustive list of all the systems visited and considered for study in all the three states, before determining the systems and sites to be surveyed in detail has been provided in Table 6.1.1. It elucidates different aspects of every single structure ranging from its years in existence, size, capacity, and present status of the structure to the general features like the utility and managerial components. On the basis of their present condition and potential to fulfill the demand of water completely or in part, each system has been categorized into three classes, essentially drawing upon subjective assessments. These three categories, A, B and C, may be described as follows:

A: Overall management and day to day maintenance of the system is good, size of the structure is apt for meeting certain part of demand of the population using it (small in case of privately owned systems and large in case of community owned systems) and capacity to retain water for a greater part of the year.

B: The systems which are managed occasionally and need major or minor repair and could supply water for about half of the year and are used occasionally.

C: The TWHS which have been completely abandoned either due to their inadequacy in supplying water or due to poor quality of water which cannot be used for any purpose, or those which have gone irreparably defunct. Such dilapidated structures are assigned C grade.

Table 6.1.1: Details of TWHS visited in Madhya Pradesh, Rajasthan and Gujarat

Table 6.1.1.A: Bavdis in Barwani District (Madhya Pradesh)

S. No.	Name of the TWHS (Village/ Town)	Years in Existence (As reported locally)	Management		Structure			Utility		Grade Assigned
			Ownership	Frequency of Repair and Maintenance in Recent Decades	Size	Post Monsoon Availability of Water	Status	Present Use	Potability (As reported by local users)	
1.	Moti Mata Bavdi (Barwani Town)	250	CPR	Never	Large	3-4 months	Needs major repair	Not in use	Not Potable	B
2.	Champa Bavdi (Barwani Town)	NA	Private	Occasionally	Large	6-8 months	Good condition	Construction work	Not Potable	A
3.	Devi Singh Bavdi-1 (Barwani Town)	100-150	Private	Occasionally	Large	6-8 months	Needs major repair	Irrigation	Not Potable	B
4.	Devi Singh Bavdi-2 (Barwani Town)	100-150	Private	Occasionally	Large	6-8 months	Needs major repair	Irrigation	Not Potable	B
5.	Devi Singh Bavdi-3 (Barwani Town)	100-150	Private	Rarely	Large	3-4 months	Needs major repair	Not in use	Not Potable	B
6.	Devi Singh Bavdi-4 (Barwani Town)	100-150	Private	Rarely	Large	3-4 months	Needs major repair	Not in use	Not Potable	B
7.	Jhamaria Bavdi (Barwani Town)	250-300	CPR	Occasionally	Small	6-8 months	Good condition	Construction work	Not Potable	A
8.	Jhalabavdi (Barwani Town)	100-150	Private	Never	Small	3-4 months	Dilapidated	Not in use	Not Potable	C
9.	Hathi Dan Bavdi (Barwani Town)	100-150	Private	Occasionally	Large	3-4 months	Needs major repair	Construction work	Not Potable	B
10.	Chakeri Bavdi (Chakeri Village)	NA	CPR	Rarely	Small	6-8 months	Needs major repair	Irrigation	Not Potable	B
11.	Mandwada Bavdi (Mandwada Village)	NA	CPR	Rarely	Small	6-8 months	Needs major repair	Irrigation	Not Potable	B
12.	Tamdi Bavdi (Sajwani Village)	150-200	CPR	Never	Large	3-4 months	Dilapidated	Livestock drinking, Irrigation	Not Potable	C

Table 6.1.1 (Contd..)

S. No.	Name of the TWHS (Village/ Town)	Years in Existence (As reported locally)	Management		Structure			Utility		Grade Assigned
			Ownership	Frequency of Repair and Maintenance in Recent Decades	Size	Post Monsoon Availability of Water	Status	Present Use	Potability (As reported by local users)	
13.	Lalbai Fulbai Bavdi (Segaon Village)	NA	Private	Regularly	Large	6-8 months	Good condition	Religious purposes	Not Potable	A
14.	Rajpur Bavdi- 1 (Rajpur)	150-200	CPR	Rarely	Small	3-4 months	Needs major repair	Drinking water	Not Potable	B
15.	Rajpur Bavdi- 2 (Rajpur)	150-200	CPR	Rarely	Small	3-4 months	Needs major repair	Irrigation	Not Potable	B
16.	Dhababavdi- 1 (Dhababavdi)	200	CPR	Never	Small	3-4 months	Dilapidated	Not in Use	Not Potable	C
17.	Dhababavdi- 2 (Dhababavdi)	200	CPR	Never	Small	3-4 months	Dilapidated	Not in Use	Not Potable	C
18.	Dhababavdi- 3 * (Dhababavdi)	300	Private	Rarely	Large	Round the year	Needs major repair	Human and livestock drinking; Irrigation	Not Potable	B
19.	Jhalabavdi * (Dhababavdi)	250	CPR (Govt.)	Occasionally	Large	Round the year	Needs major repair	Irrigation	Not Potable	B

* TWHS selected for detailed survey

Table 6.1.1.B: Bavdis in Khargone District (Madhya Pradesh)

S. No.	Name of the Structure	Years in Existence (As reported locally)	Management		Structure			Utility		Grade Assign-ed
			Ownership	Frequency of Repair and Maintenance in Recent Decades	Size	Post Monsoon Availability of Water	Status	Present Use	Potability (As reported by local users)	
20.	Kali Mata Bavdi (Khargone Town)	300-400	Private	Occasionally	Large	Round the year	Good condition	Used as ice-cream parlour	Not Potable	A
21.	St. Jude's School Bavdi (Khargone Town)	100-150	CPR	Never	Small	2-3 months	Dilapidated	Not in use	Not Potable	C
22.	Gopalpura Bavdi (Khargone Town)	300-400	CPR	Never	Small	Dry	Dilapidated	Not in use	Not Potable	C
23.	Kasar Bavdi (Khargone Town)	200	Private	Occasionally	Large	6-8 months	Needs major repair	Irrigation	Not Potable	B
24.	Nandgaon Bavdi-1 (Nandgaon Village)	200	CPR	Never	Small	Dry	Dilapidated	Not in use	Not Potable	C
25.	Nandgaon Bavdi-2 (Nandgaon Village)	200	CPR	Never	Small	Dry	Dilapidated	Not in use	Not Potable	C
26.	Gauridham Bavdi (Khargone Town)	100-150	Private	Occasionally	Large	8-10 months	Needs major repair	Construction, Irrigation	Not Potable	B
27.	Sailani Bavdi (Sailani Village)	NA	CPR	Never	Small	2-3 months	Dilapidated	Not in use	Not Potable	C
28.	Ojhara Bavdi-1 (Ojhara Village)	NA	CPR	Never	Small	Dry	Dilapidated	Not in use	Not Potable	C
29.	Ojhara Bavdi-2 (Ojhara Village)	NA	CPR	Never	Small	Dry	Dilapidated	Not in use	Not Potable	C
30	Temla Bavdi* (Temla Village)	300	CPR	Occasionally	Large	Dry	Needs major repair	Storage tank	Not potable	B

* TWHS selected for detailed survey

Table 6.1.1.C: Wells in Barmer District (Rajasthan)

S. No.	Name of the Structure (Town/ Village)	Years in Existence (As reported locally)	Management		Structure			Utility		Grade Assigned
			Ownership	Frequency of Repair and Maintenance in Recent Decades	Size	Post Monsoon Availability of Water	Status	Present Use	Potability (As reported by local users)	
31.	Village Well (Sitli Gaon)	300-400	CPR (Govt.)	Occasionally	Large	6-7 months	Needs major repair	Domestic use except drinking	Not Potable, Saline	B
32.	Village Well (Charlai Kalan)	100-150	CPR	Never	Small	Dry	Dilapidated	Not in use	Not Potable	C
33.	Village Well (Nevari Gaon)	NA	CPR	Never	Large	Dry	Dilapidated	Not in use	Not Potable	C
34.	Village Well (Bankiawas Kalan)	500	CPR	Rarely	Large	6-7 months	Needs major repair	Drinking	Potable, but Saline	B
35.	Village Well (Mandali)	NA	CPR (Govt.)	Occasionally	Large	Round the year	Good condition	Drinking	Potable, but Saline	A
36.	Village Well (Nagana*)	800-900	CPR (Govt.)	Occasionally	Large	Round the year	Good condition	Drinking	Potable, but Saline	A

* TWHS selected for detailed survey

Table 6.1.1.D: Wells in Jodhpur District (Rajasthan)

S. No.	Name of the Structure	Years in Existence (As reported locally)	Management		Structure			Utility		Grade Assigned
			Ownership	Frequency of Repair and Maintenance in Recent Decades	Size	Post Monsoon Availability of Water	Status	Present Use	Potability (As reported by local users)	
37.	Village Well (Pagbavdi-1)	NA	CPR (Govt.)	Never	Large	6-8 months	Needs major repair	Not in use	Not Potable, Saline	B
38.	Village Well (Pagbavdi-2)	NA	CPR	Never	Large	6-8 months	Needs major repair	Not in use	Not Potable, Saline	B
39.	Village Well (Basni Lachhaa)	125-150	CPR	Rarely	Large	Round the year	Needs major repair	Livestock drinking	Not Potable	B
40.	Village Well (Thabukada)	NA	CPR	Never	Small	Dry	Needs major repair	Not in use	Not Potable, Saline	B
41.	Village Well (Dahikada)	NA	Private	Rarely	Large	Round the year	Good condition	Drinking, Irrigation	Non Potable, Saline	A
42.	Village Well (Godavas*)	600	CPR	Rarely	Large	Round the year	Good condition	Drinking, Irrigation	Potable, Saline	A

* TWHS selected for detailed survey

Table 6.1.1.E: Talavs in Kutch District (Gujarat)

S. No.	Name of the Structure (Village/ Town)	Years in Existence (As reported locally)	Management		Structure			Utility		Grade Assigned
			Ownership	Frequency of Repair and Maintenance in Recent Decades	Size	Post Monsoon Availability of Water	Status	Present Use	Potability (As reported by local users)	
43.	Narayan Sarovar (Village Kayyari)	300-400	Govt.	Occasionally	Large	6-8 months	Good condition	Bathing, Religious purpose	Not Potable	A
44.	Hamirsar (Bhuj Town)	400	Govt.	Rarely	Large	Round the year	Needs major repair	Domestic	Not Potable	B
45.	Desalsar (Bhuj Town)	400	Govt.	Rarely	Large	Round the year	Needs major repair	Domestic	Not Potable	B
46.	Rata Talav (Village Vira)	150	CPR	Never	Large	6-7 months	Needs major repair	Drinking	Not Potable	B
47.	Upadhyay Talav (Village Vira)	150	CPR	Never	Small	6-7 months	Needs major repair	Domestic	Not Potable	B
48.	Sidhsar (Anjar Town)		CPR	Never	Medium	6-7 months	Needs major repair	Livestock Drinking	Not Potable	B
49.	Anjar Talav (Anjar Town)		CPR	Never	Small	2-3 months	Dilapidated	None	Not Potable	C
50.	Wandai Talav (Village Wandai)		Trust	Regularly	Large	Round the year	Good condition	Bathing, Religious purposes	Not Potable	A
51.	Chhatasar, Sumrasar, Chatasar (Village Tera)*	300	CPR	Occasionally	Large	Round the year	Needs major repair	Drinking	Potable	A
52.	Village Talav (Village Reha Mota)*	100	CPR	Never	Large	Round the year	Needs major repair	Cooking	Not Potable	B

* TWHS selected for detailed survey

6.1.2 Brief Overview of Systems Selected

Keeping these local specificities in view the potential of selected systems in terms of long-term sustainability can be described in brief, as follows:

(i) *Bavdis in South western Madhya Pradesh*: These exist in huge numbers. But, due mainly to their typically small size and limited storage capacity, these are not probably the best options for meeting community water needs. However, as observed by the hydrogeologists and water engineers, it is possible to deepen existing talavs and dig new ones, which in turn would recharge bavdis. In Dhababavdi (Barwani district) the currently functioning two bavdis serve limited purpose and, clearly, shall not be able to address the water scarcity problem of the entire village.

(ii) *Wells in Western Rajasthan*: Wells as TWHS in the western parts of Rajasthan have continued to prove useful even during summer months in the driest geoclimatic region of India. Unlike bavdis, wells are extensively used by the rural communities and are well maintained. All the wells visited in this region during the peak summer season had good supply of water and the local perception about its quality was positive. An important hydrogeological characteristic of these wells surveyed was that the structures had been linked to underground perennial streams/ channels. Also, these wells had been built with reference to the surrounding nadis (TWHS by themselves) so as to receive water recharged through them. Such ingenious selection of location and construction of the structures ensured a steady supply of water in the wells. These wells hold much potential to be revived and modernized. One most effective approach shall be to desilt, deepen and widen the concerned nadis; this will ensure a substantial increase in availability of water in the wells, which may be stored for a long period of time. These structures are also viable options in these regions where piped water system is most likely to fail due to very low level of groundwater tables.

(iii) *Talavs in Kutch, Gujarat*: Almost all parts of the Kutch region have suffered substantial groundwater depletion and salinity impress. High incidence of poor groundwater bearing formations has resulted in severe water crisis in the region. Talavs certainly remain an important solution to the water problem in Kutch. In many villages visited, villagers considered water from local talavs to be of good quality and that water is available in them during prolonged spells of summer. The structures in the surveyed villages are unique examples of interconnected talavs, specially designed to prevent drinking water mingling with water in other talavs meant for washing or bathing purposes. In terms of size and capacity talavs are of large dimensions. These are in dire need of revival and modernization and can surely prove valuable in addressing the water shortage problem in Kutch region. Unlike the saline groundwater, talavs retain potable water and also recharge surrounding aquifers as also other TWHS like wells.

6.1.3 Consumption Pattern of Water and Dependence on TWHS

The principal sources of water in sample villages were wells, talavs, handpumps, tubewells and bavdis. The consumption pattern of water in all the sample villages reveals that the water needs of the villages with reference to the standard requirements fall short by between 24 to 46 per cent (Table 6.1.2). The pattern of present water usage met through different sources reveals that whereas in villages like Nagana in Rajasthan and Tera in Kutch, the dependence on selected TWHS is almost cent per cent. In Temla of Madhya Pradesh, almost all of the village supply is met through tubewell, which is a modern source (Table 6.1.3). The remaining villages depend on both the modern and traditional sources. Further, to establish the factors affecting the per capita consumption of water in the sample villages multiple regression analyses were carried out. The variable family size (TSNO) proved to be the significant factor influencing the per capita consumption of water such that with a unit increase in the family size the per capita consumption declined. Table 6.1.4 provides the list of explanatory variables along with their values of regression coefficients, which were found significant in the analyses done for individual states.

Table 6.1.2: Per Capita Consumption and Deficiency with Reference to Standard Quantity in Sample Villages

Village	Per Capita Consumption (in litres per day)	Deficiency (in per cent)
Dhababavdi	23.52	46.11
Temla	30.70	29.19
Nagana	30.64	39.27
Godavas	32.77	37.15
Tera	28.00	36.47
Reha Mota	34.91	24.07

Table 6.1.3: Dependence of Sample Households on TWHS and Modern Sources of Water Supply

Village	Selected TWHS	Other TWHS	Modern Source
Dhababavdi	2.56	34.93	62.51
Temla	2.51	3.29	94.20*
Nagana	17.87	0.22	81.91**
Godavas	57.37	1.47	41.16
Tera	97.1	2.88	Highly unreliable
Reha Mota	63.3	3.66	33.1

*Water from tubewell is temporarily stored in the bavdi
**Water from well is supplied through stand posts

Table 6.1.4: Overall Summary of Multiple Regression Analyses

State/ Level of significance	1% level of Significance	5% level of Significance
Madhya Pradesh	TSNO (-0.621)	PCINC (0.188)
Rajasthan	TSNO (-0.513)	
Gujarat	TSNO (-0.702)	

6.1.4 Quality of Water in the TWHS

A commonly held observation disfavouring TWHS as potential sources of potable water concerns the ‘unprotected’ and ‘unsafe’ nature of the water. This important dimension of quality of water of TWHS must be taken into consideration in evaluating their potential. Water samples from the surveyed TWHS were collected for chemical analyses. In order to establish the bacterial contamination, if any, bacteriological tests were conducted on water samples in the laboratory following scientific instructions.

Potable water should not be saline, should be free from bacteria and dissolved chemical salts, which may be harmful. As per standards of purified water, it should have pH ranging between 8-10; turbidity (Silicon Scale) of 10.0; total dissolved solids (TDS) should be less than 1000 parts per million (ppm) and should be colourless and odourless. The water can be considered potable only if, in addition to the aforesaid standards of chemical composition, it is also free from harmful bacteria. The water samples from the all the sites have also been tested for the presence or otherwise of the most commonly found coliform bacteria. According to the standards the presence of 10 mpn concentration of bacteria per 100 ml of water is within permissible limits.

Irrespective of the fact that most villagers use the water of TWHS for drinking, cooking and other domestic purposes, the scientific tests indicate deficiencies in water quality. In most cases, as in the surveyed TWHS and presented in Table 6.1.5, the quality of water can be upgraded substantially through cost-effective methods of treatment. Whether, some sources are to be abandoned, primarily due to lack of any scope to improve water quality, even up to the level of being used for domestic purposes (other than human drinking) only, should be left exclusively to the discretion of the scientific experts.

Table 6.1.5: Chemical and Bacteriological Test Results, All States

Village	Water Source	Chemical Analysis	Bacteriological Analysis
Dhababavdi	Dhababavdi and Jhalabavdi	Potable	Coliform Bacterial Concentration very high, not fit for drinking, cannot be treated
	Hand Pump	Potable	Test not required
Temla	Bavdi*	Potable	Suitable
	Hand Pump	Potable	Test not required
Nagana	Well	Potable but filtration essential, as TDS is high	High bacterial concentration, needs chlorination treatment
Godavas	Well	Potable but Alum treatment/ filtration required	High bacterial concentration, needs chlorination treatment
Tera	Talav	Potable	Bacteria Concentration high, purification required
Reha Mota	Talav	Potable	Coliform bacterial concentration very high, needs treatment

Notes: * Bavdi is used as storage tank for water drawn from borewell.
Chemical Test for pH range, TDS, Ca, Mg, Na, CO_3, HCO_3, SO_4, Cl; w.r.t. standard upper limits were conducted.

6.2 Revival of TWHS

6.2.1 Technological and Institutional Options Towards Sustainability of TWHS

A number of technological options to revive/ modernize the TWHS have been put forth by the hydrogeological and engineering experts. Most of the considered suggestions have been highly discrete (specific to the system or site *per se*) and often have incorporated ideas from local inhabitants.

Madhya Pradesh

Dhababavdi

Cleaning of the debris filled at the bottom from the Jhalabavdi and Dhababavdi, repairing of the bavdi walls and cleaning of the area around the bavdis are suggested. One small recharge structure (check dam) on the stream can also be built.

Temla

Temla Bavdi is a shallow well having hard rocky strata in the bottom and does not store sufficient volume of water throughout the year. Information gathered during the field survey, indicates that bavdi is used for livestock drinking for about 50 days after monsoon, and thereafter it is used for storing piped water brought from distant bore wells. Considering these points, masonry repair to the bavdi structure is suggested.

Construction of a recharge talav of dimensions 30 m x 30 m x 1.5m adjacent to the handpump close to bavdi is suggested. The recharge talav may increase the yielding capacity of hand pump borehole. Direct recharging of hand pump from talav water can also be tried after exacting the process. For recharging the Borehole 1, a percolation tank neighbouring the borehole would increase the yield of the borehole naturally. Another potential suggestion is that of artificial pouring of water in the tube well after allowing it to pass through a filter bed. The percolation barrier (embankment) of 60 metres long is suggested. A pit of 30 m x 30 m x 1.5m dimensions is suggested in the upstream side of the tank. Direct injection of tank water into the borehole is also suggested. However this process will need proper formatting. For the Borehole 2 a recharge pit of size of 20 m x 20 m is suggested near the borehole. Small gully plugs are also suggested near this borehole. Further, for recharging the hand pump 2, a check dam on a small stream passing in the west of the village is suggested. Check dam should be 20 m long across the stream.

Construction of these recharge structures near the water supply boreholes will increase the yield of the boreholes. The percolation pit near this hand pump will help increase the yield of the hand pump. Once the percolation pit is ready, a process of direct recharge (pouring) of water from the pit to the hand pump 1 will be evolved. The pit water will pass through a natural filter and it can be carried through a PVC pipe to fall in the hand pump casing. It is necessary to keep this borehole operational for a long time. Construction of a percolation tank will increase the discharge of borehole and the period of constant discharge may also increase.

Rajasthan

Nagana

Nadis as potential recharge structures hold the key to revival of wells. Sevalia nadi is located near the water supply well and revival of this nadi may help in recharging the old well. Similarly Undaria and Pilundia nadis store huge volumes of rainwater. All these nadis if desilted and maintained before the monsoons every year may increase the groundwater levels and also reduce the salinity of adjoining areas. Other areas, which do not receive rainfall recharge, may be due to high runoff or due to non-favourable rock type, have saline groundwater. Revival of nadis will definitely help such areas in conserving fresh water.

Godavas

The area is plain land of Thar Desert where surface water runoff is less and the groundwater recharge is limited due to the occurrence of calcrete and claystones. The water level of the tubewells is declining at a rate of 3 metres per year due to overdraft, this suggests that the life of tubewells may be about five more years.

Gujarat

Tera

The wells in areas of Tera and neighbouring villages have saline water, which may be accrued to the existence of saline water in the pliocene rocks found in these areas. Cretaceous sandstone, which are suitable for tubewell drilling, are found as distantly as 0bout 20 km away from Tera. A regional water supply scheme supplies water from tubewells in Netra to 11 villages wherein village Tera falls at the tail end. These tubewells cannot cater to the water needs of all the eleven villages regularly. Cretaceous sandstone aquifer is over stressed because of its limited extension and recharge, indicated by a fall of 1 to 4 metres in water levels of tubewells every year.

Talavs form the only fresh water bodies as in case of Tera, therefore, to store large volumes of rainwater revival and maintenance of these talavs is essential. However, a major concern in determining the potability of the talav water is that of its bacteriological contamination. The bacteriological test results show high growth of bacteria in the talav water. Treatment of this water through intensive chemical sterialisation is highly recommended to render the water as potable.

Reha

Reha talav is a traditional talav constructed since olden times to harvest rainwater by utilising the geographically favourable location. The talav can store 40000m^3 of rainwater. The area around Reha Mota consists of cretaceous sandstones, which are potential aquifers for groundwater development. Water supply to the village is based on one such tubewell. To meet the water needs of the village another tubewell is being drilled. This sandstone aquifer is overexploited and there is continuous fall in water levels in tubewells. A major concern here is that of recharging of the existing aquifer since the water levels of the aquifer have been reported to be declining rapidly. The farmers drill deep tubewells to draw water for irrigation purposes.

6.2.2 Issues in Financing Revival and Managing TWHS

Through village level focus group discussions (FGDs) as also structured household level surveys issues of management and maintenance of TWHS have been dealt with. Table 6.2.1 presents some relevant aspects. In case of the well in Nagana in Rajasthan and the talav in Tera in Gujarat management and maintenance of the TWHS were done by the local community. These are the villages where the use of water from TWHS has been extensive and also the quality of water has been well maintained. In the remaining cases, a preference has been expressed for complete or partial involvement of state government in managing and maintaining the sources. In these villages, the general lack of confidence in the efficacy of the sarpanchs in managing these sources is striking. The possibility of public and private participation in financing the revival of the TWHS in these villages may be explored. However, as may be seen from Table 6.2.2 especially the bavdis may not prove to be adequate sources of water due to their small size.

Table 6.2.1: Management Issues in Revival and Maintenance of the TWHS

Bavdi		Well		Talav	
Dhababavdi	Temla	Nagana	Godavas	Tera	Reha Mota
Presently privately owned, Government should take over and manage	Government/ Panchayat managed : Distrust among the people regarding the usage of funds	Panchayat managed	Improper local management	Community managed	Government should take up the management
Sarpanch is illiterate: Lack of leadership	Lack of leadership, Sarpanch illiterate	Leadership is caste biased		The local leaders are highly motivated and concerned for the water management	
No participation from women	Women participated but reported being ignored	Women do not have a say in the local management	Lack of sense of respon-sibility for maintenance of the existing structures	People are united for maintenance of the system	Generally people were not interested in taking up the maintenance and management of their water supply.

Table 6.2.2: Structural Issues Relating to the Revival of TWHS

Bavdi		Well		Talav	
Dhababavdi	Temla	Nagana	Godavas	Tera	Reha Mota
Structural					
Receding water table	Receding water levels	Depleting groundwater levels	Depleting water levels Salinity increases with depleting water levels	Groundwater is reported to be saline	
	Poor accessibility	Poor accessibility	Poor accessibility	Poor accessibility	Poor accessibility
Structure is small		Groundwater is becoming saline		Huge capacity and favourable topography	

Unsuitable for human drinking	Water unsuitable for human drinking			Only sweet water source	Reported to be unsuitable for drinking but good for cooking
Desilting of catchments would improve water table	Desilting of local talav is essential for recharge of the bavdi	Desilting of local talav would improve the water and reduce salinity		Some people reported to have had diseases because of the bacterial contamination of the water during late summers	Desilting would improve the water level

6.2.3 Willingness to Pay for Water

Whereas hydrogeological and structural engineering studies worked out the interventions that would revive/ modernize the specific TWHS on a long term sustainability basis, the estimation of both the capital cost as well as O&M indicating the financial investment were done. Such estimates represent the total use value of potable water meant for domestic consumption only; the existence value of the water becomes irrelevant. Also, the nature of benefits of having access to good quality water is very much within the knowledge of the potential users. For instance, it can substantially save the average daily time spent and distance covered per family for fetching water. Table 6.2.3 indicates the magnitude of the loss of time and distance traversed by the household members in the sample villages. While recognizing the time consumption dimension, we have desisted from using the usual opportunity cost concept here due to its obvious limitations of applicability in our study.

Table 6.2.3: Daily Average Time Spent and Distance Covered in Collection of Water in Sample Villages

Village (State)	Distance Covered (in metres)	Time Spent (in hours)
Dhababavdi (Madhya Pradesh)	2864.70	4.44
Temla (Madhya Pradesh)	1528.02	5.25
Nagana (Rajasthan)	6476.10	5.79
Godavas (Rajasthan)	2888.91	7.14
Tera (Gujarat)	3733.70	5.29
Reha Mota (Gujarat)	7207.50	6.81

It may, hence, be held that the assessment of WTP undertaken in the study falls within the broad purview of the cost-benefit analysis. Assuming that the entire cost of revival/ modernization would be shared between all the households in the village, an assessment of the willingness to pay for the improvised structures was made. The household surveys were based upon structured questionnaires prepared in the CVM framework. The introduction of the option of mode of payment was supposed to help reveal respondents' actual ability to pay for the amenities. A similar exercise in WTP was also conducted for laying a network of piped water system to provide household level tap connections.

The most redeeming aspect of the WTP exercise was that a substantial 65 per cent of all households surveyed responded in the negative (that is they were not willing to pay any amount whatsoever) for either or both the hypothetically proposed facilities. Despite having a series of independent variables, indicating the most likely socio-economic factors, regressed with the amount of WTP, the state level results showed only per capita consumption of water (PCHUMQ) in Madhya Pradesh and Rajasthan and caste of the household (CASTE) in Gujarat as the significant variables affecting the WTP. However, similar regressions when run for Rajasthan none of the variables were found to be significant (Table 6.2.4).

Table 6.2.4: Overall Summary of Logistic Regression Results

State/ Level of Significance	1% level of Significance	5% level of Significance	10% level of Significance
Madhya Pradesh			PCHUMQ (1.035)
Rajasthan			
Gujarat	CASTE (0.174)	PCHUMQ (1.049)	

In fact, a close examination of the nature and extent of households' WTP provides interesting insights into such a pattern of response. First, most households in the Rajasthan villages are living in extreme poverty and, naturally, have refused to pay at all for the water from either TWHS or piped systems (Table 6.2.5). The villagers are perfectly aware that the existing wells, from where they have been drawing water free even during the peak summer months, shall continue to meet their minimum basic demand for potable water. However, if extreme poverty could lead to negative response for paying for water, in Dhababavdi (the MP village) quite a few villagers living below poverty line have expressed their willingness to pay even small sums for water facilities. This is so, as this village has practically exhausted all existing sources and the value for water has clearly risen for them.

Second, very unlike the capital cost, most villagers in all the surveyed villages were willing to pay for the O&M for TWHS; in many cases the estimated contribution for O&M for the proposed piped system was much higher than that for TWHS. People's willingness to contribute labour free indicates the preference for the revival/ modernization of the TWHS. An important aspect of this exercise in assessing WTP is that even the most sophisticated methods of valuation may be inadequate to elicit information on the WTP behaviour if the respondents refuse to participate in the 'bidding' process due mainly to abject poverty and rejecting the very proposal that potable water could be priced for the rural poor.

Table 6.2.5: Willingness to Pay Across Sample Villages

(Percentages)

Particulars	Madhya Pradesh		Rajasthan		Gujarat	
	Dhababavdi	Temla	Nagana	Godavas	Tera	Reha Mota
WTP_{TWHS}	26.8	11.8	14.3	4.7	77.3	11.8
WTP_{PIPE}	22.0	9.8	5.7	-	18.2	7.8
$WTP_{O\&MTWHS}$	39.0	76.5	97.1	100.0	93.2	90.2
$WTP_{O\&MPIPE}$	29.3	13.7	17.1	-	72.7	13.7
$WTP_{LABOURTWHS}$	92.7	84.3	97.1	100.0	77.3	74.5

6.3 Concluding Observations

It was apparent that TWHS were not or will not be able to cater to the total requirement of drinking water in the villages, mainly due to the rise in population in the past decades. Nevertheless, if revived/ repaired and, importantly, the ownership is shifted from the present private to its original community based, these sources can be of substantive use, especially, during summer.

Piped water system, though preferable, has implications of increasing cost in future either due to increase in population or depletion of groundwater or both. Additionally, the ubiquitous problem of unreliability of piped water supply has serious implications for considering alternative sources.

Hydrogeology specific technological strategies to harness rainwater and modernise TWHS need to be explored as enhanced supply per se can reduce costs significantly. In such ventures whether and how state can intervene or shall seek private participation, both for financing and providing technical and management support is an issue to be explored. In TWHS, the trickier issue is management with community participation. The control over the system by the local dominant group is difficult to wish away.

Interestingly, the large-scale prevalence of TWHS in its varied forms in the three states has not been adequately documented in the rather limited literature on the subject. Locating the TWHS through the field survey in itself was an important aspect of the study.

References

Agarwal, Anil and Sunita Narain (Eds.) (1997), *Dying Wisdom: Rise, Fall and Potential of India's Traditional Water Harvesting Systems*, Centre for Science and Environment, New Delhi.

Agarwal, Anil, Sunita Narain and Indira Khurana (2001), *Making Water Everybody's Business: Practice and Policy of Water Harvesting*, Centre for Science and Environment, New Delhi.

Barah, C. Bhuban (1996), *Traditional Water Harvesting Systems: An Ecological Economic Survey*, New Age International Limited, New Delhi.

Bhagyalakshami, J. (2001), "Water Harvesting for Drought- Prone Areas", *Yojana*, 45 (1 and 2).

Central Ground Water Board District Report: Khargone, 2000

Das, Keshab (2001), "Rural Drinking Water Supply in India: Issues and Strategies", in Sebastian Morris (ed.) *India Infrastructure Report 2001: Issues in Regulation and Market Structure*, 3iNetwork, Oxford University Press, New Delhi, 2001.

Das, Keshab and B. L. Kumar (1998), "A Validation Study of Habitations Not Covered under the Rural Drinking Water Programme in Gujarat", mimeo, Gujarat Institute of Development Research, Ahmedabad.

District Census Handbook, Barmer District, Census of India, 1991.

District Census Handbook, Jodhpur District, Census of India, 1991.

District Census Handbook, Khargone District, Census of India, 1991.

District Census Handbook, District Kutch, Census of India, 1991.

Government of Gujarat, (2001), *Socio Economic Review: Gujarat State, Government of Gujarat, 2000-2001.* Gandhinagar.

Hanemann, W. Michael (1994), "Valuing the Environment through Contingent Valuation", *The Journal of Economic Perspectives*, 8 (4).

Mehta, Aasha Kapur and Nikhila Menon (2001) "Pricing of Rural Drinking Water: A Study of Willingness and Ability to Pay in Western India" *Journal of Social and Economic Development,* 20(1).

"Norms for Village Water Supply Diluted" *The Times of India*, Ahmedabad Edition, June 26, 2002, p. 7.

Portney, Paul R (1994), "The Contingent Valuation Debate: Why Economists Should Care", *The Journal of Economic Perspectives*, 8 (4).

Raj, (1996), “Rural Housing in India”, *Kurukshetra,* 44 (8 and 9).

Raju, K. C. B., (1990), “*Hydrogeology of Kutch Region*” (Unpublished report).

Reddy, D. Narasimha, B. C. Barah and T. Sudhakar (1992), “Decline in Traditional Water Harvesting Systems”, *Indian Journal of Agricultural Economics,* 48 (1).

Reddy, V. Ratna (1999) “Pricing of Rural Drinking Water: A Study of Willingness and Ability to Pay in Western India” *Journal of Social and Economic Development,* 2 (1).

Sarvekshana, (2001) XXIII (3), 82nd Issue (Special), Jan-March 2000, p. 55.

Vaidyanathan, A (2001), *Tanks of South India,* Centre for Science and Environment, New Delhi.

Vohra, P.H. (2001) “Water Harvesting: A Suggestion” *Yojana*, Vol.45 Issue (July)