A STUDY ON FUNCTIONING AND USE OF HANDPUMPS IN PALAKKAD DISTRICT IN KERALA, INDIA.

MASTER OF SCIENCE THESIS
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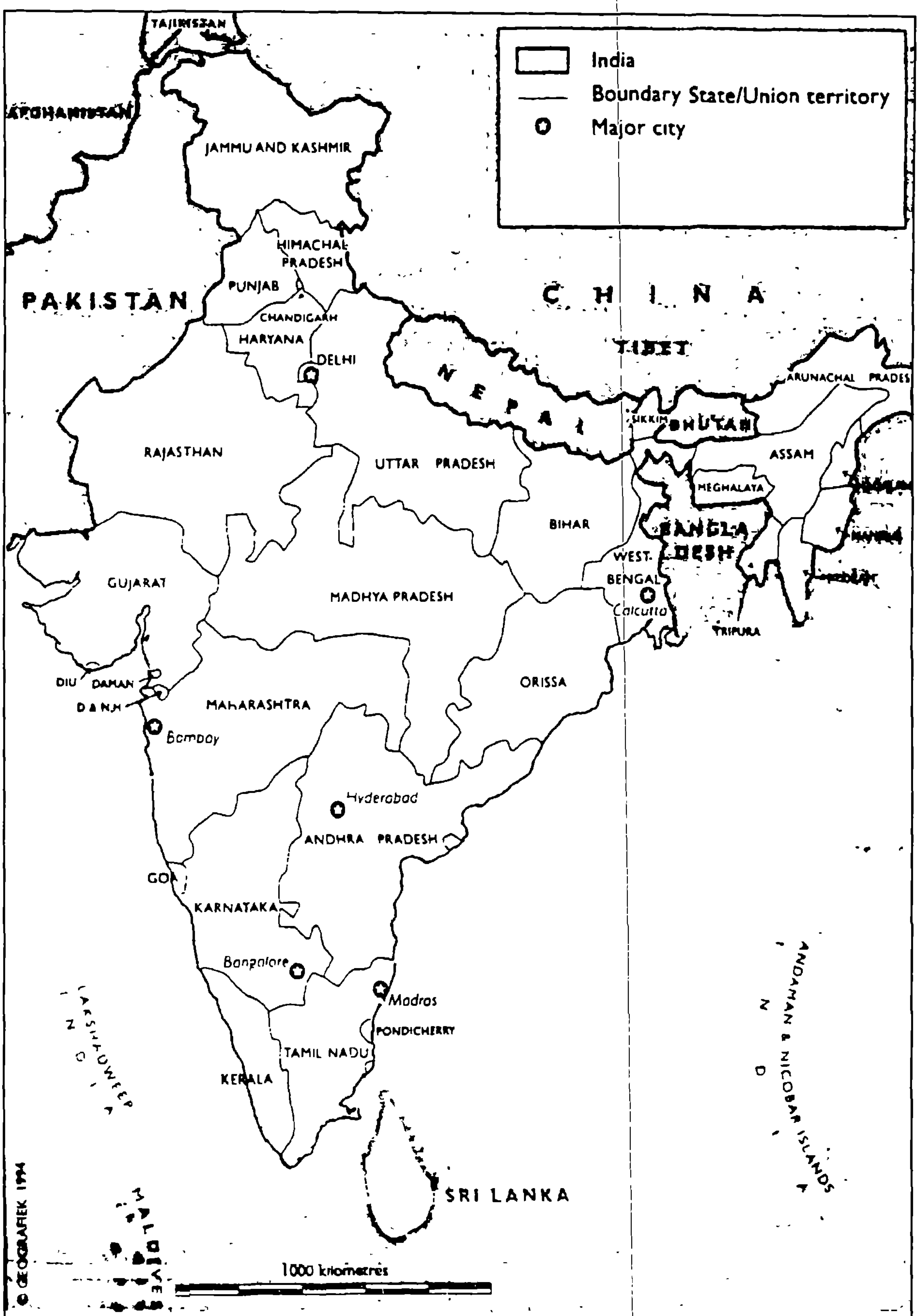
India
Boundary State/Union territory
Major city
JAMMU AND KASHMIR
HIMACHAL PRADESH
PUNJAB
CHANDIGARH
HARYANA
DELHI
PAKISTAN
CHINA
TIBET
NEPAL
SIKKIM
BHUTAN
ARUNACHAL PRADESH
ASSAM
MEGHALAYA
BANGLADESH
TRIPURA
RAJASTHAN
UTTAR PRADESH
BIHAR
WEST BENGAL
Calcutta
GUJARAT
MADHYA PRADESH
ORISSA
DIU
DAMAN
MAHARASHTRA
Bombay
Hyderabad
ANDHRA PRADESH
KARNATAKA
Bangalore
Madras
PONDICHERRY
TAMIL NADU
KERALA
SRI LANKA
ANDAMAN & NICOBAR ISLANDS
1000 kilometres
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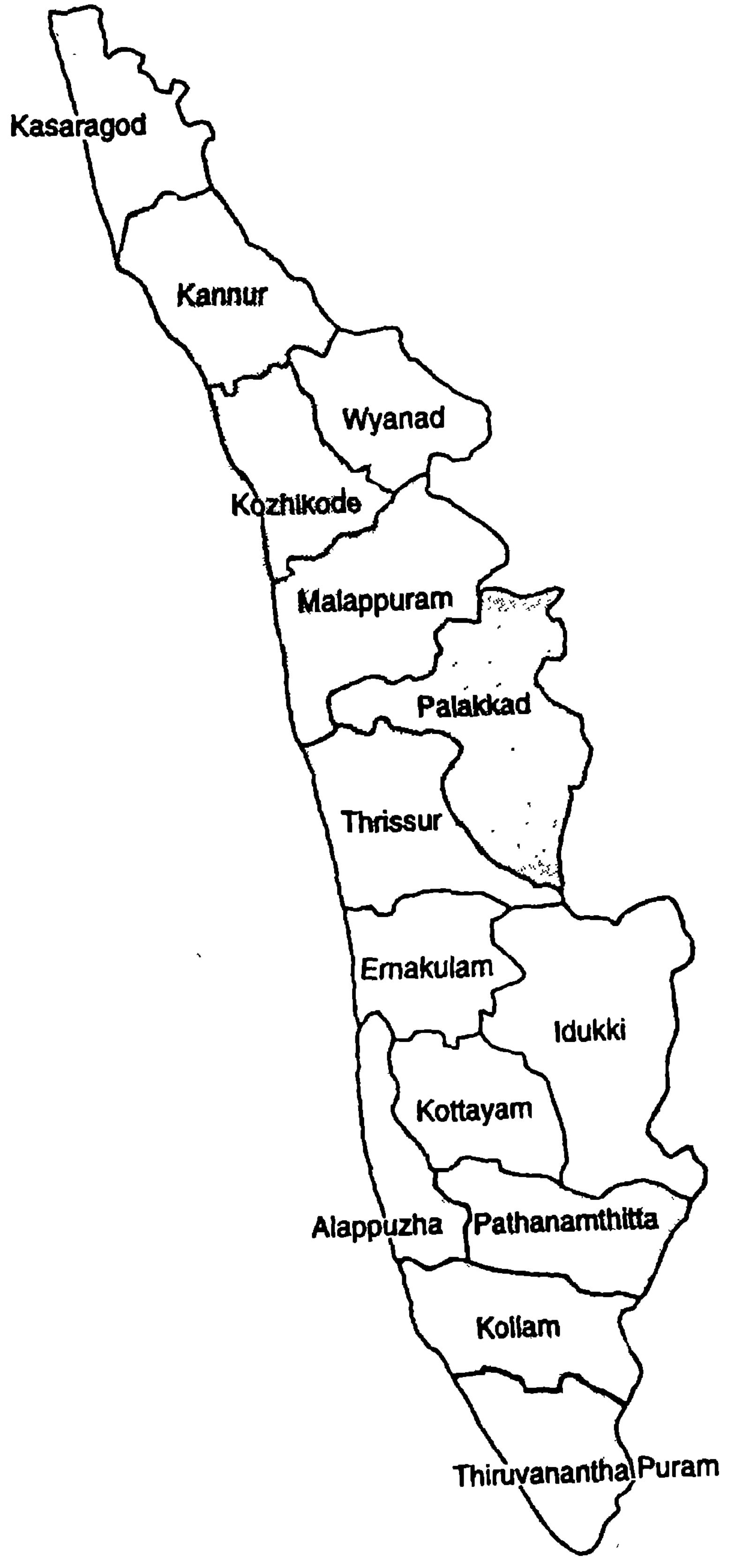
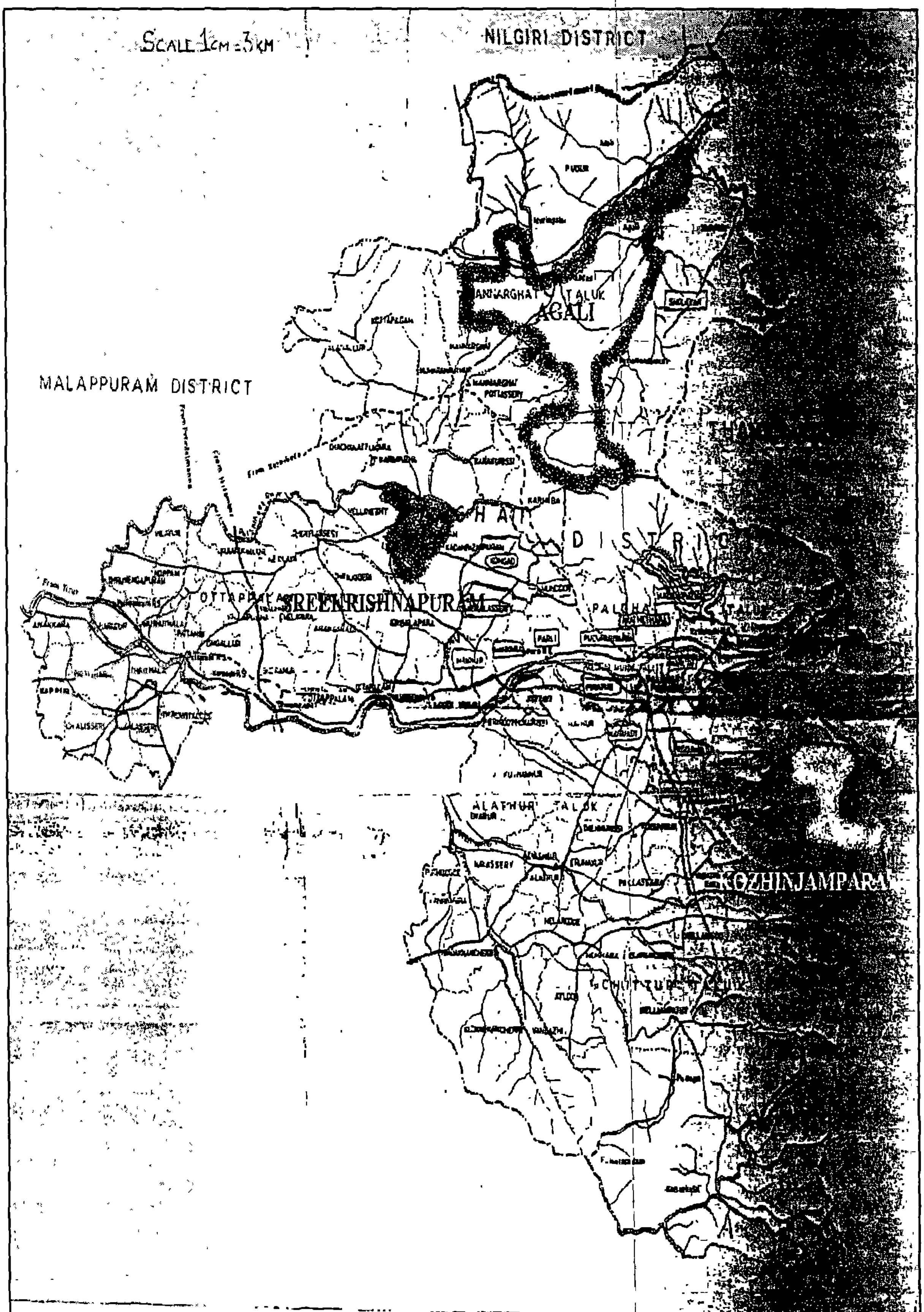
Map of India



Map of Kerala showing Palakkad District



Map of Palakkad showing selected Panchayaths under study

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S Sethu kumar,
Delft,
25 03 1997

Abstract

At a cost reduction of 60 to 80 percent, handpump based water supply can potentially provide a wider coverage and greater reliability than that can be achieved with more sophisticated systems which offer higher levels of service. In India, more than 300 million people depend on handpumps for their drinking water and this is taken to be as an appropriate method for providing drinking water to isolated communities and villages in rural India.

Borewell with handpumps are one of the major sources of water supply in the rural areas of Palakkad district, in Kerala state, India. About 2200 borewells with handpumps were installed in the district. Problems with respect to quality, quantity and user acceptance of handpump water supply were noticed in this area. Several studies have reported high iron content in the handpump water of the area.

The objective of the study was to evaluate the performance of handpumps with regard to functioning and use and to suggest solutions to improve the existing situation. The methodology consisted of literature study and two months field work in Palakkad. The literature study was carried out in IRC, Hague and in IHE, Delft. Specific literature on handpump programmes in Palakkad were collected from the offices of Kerala Water Authority at Palakkad.

Three Panchayaths, one in hilly terrain, one from a low land area with perennial water source, and one from a water scarce low land area were selected for the present study. Twenty handpumps spread out in six wards of these three Panchayaths were studied. In each location standardized interviews were conducted. Opinion from 178 households living near the selected 20 handpump locations were obtained, out of which 123 were handpump users. A water resource map of the existing water sources was prepared with the help of the community members. Water samples from all these handpumps and another eleven most commonly used traditional water sources were collected and tested.

The study reveals that nineteen out of twenty handpumps were functioning but only half of them met the discharge standards set by the Bureau of Indian Standards (BIS). It was found that about 25% of the pumps had unacceptable levels of leakage. Also a high breakdown frequency of once in six months in these systems were noticed. Nine out of twenty pumps were not used for drinking and cooking as a result of bad taste due to the excess concentration of iron in the water. It has been noticed that, wherever the pump is heavily used, it is used for drinking and cooking. Fourteen out of twenty water samples had unacceptable levels of iron contents and sixteen out of twenty water samples showed fluoride concentrations above the limits set by the BIS for drinking water.

The study recommends (i) that ground water quality investigations should become part and parcel of all handpump programmes, (ii) to make alterations in the existing India Mark II pumps to facilitate village level operation and maintenance, and (iii) to explore the possibility of surface water as an alternative source of water supply where ground water quality is unacceptable.

Contents

List of Abbreviations

AD	-	Anno Domini.
ARP	-	Accelerated Rural Programme
ARWSP	-	Accelerated Rural Water Supply Programme.
BC	-	Before Christ.
BIS	-	Bureau of Indian Standards.
CGWB	-	Central Ground Water Board.
CWC	-	Central Water Commission.
CWRDM	-	Centre for Water Resources and Development
DPR	-	Detailed Project Report.
DRW	-	Draught Relief Works.
DTH	-	Down The Hole.
EC	-	Electrical Conductivity.
GDP	-	Gross Domestic Product
GOI	-	Government of India.
GOK	-	Government of Kerala.
IAS	-	Indian Administrative Services.
IDWSSD	-	International drinking Water Supply and Sanitation Decade.
IMRB	-	Indian Market Research Bureau.
KWA	-	Kerala Water Authority.
KSPCB	-	Kerala State Pollution Control Board.
MCM	-	Million Cubic Metres
MERADO	-	Mechanical Engineering Research And Development Organisation
MNP	-	Minimum Needs Programme.
NGO	-	Non Government Organisation.
ORG	-	Operation Research Group
PHC	-	Primary Health Centre.
PHED	-	Public Health Engineering Department.
RGNDWM	-	Rajiv Gandhi National Drinking Water Mission
Rs	-	Indian Rupees
SC	-	Schedule Caste.
SCP	-	Special Component Plan.
ST	-	Schedule Tribe.
SEU	-	Socio Economic Unit
TSP	-	Tribal Sub Plan
UNDP	-	United Nations Development Programme
UNICEF	-	United Nations Children's Fund.
US	-	United States.
UT	-	Union Territory.
VLOM	-	Village Level Operation and Maintenance.
WHO	-	World Health Organisations.

Chapter 1

Introduction

Safe drinking water is one of the most important needs of humanity. Scarcity and misuse of fresh water pose a serious threat to sustainable development and protection of the environment. Water borne and water washed diseases are common in developing countries, resulting in high mortality and sickness rates. One of the reasons is inadequate quantity and poor quality of traditional water sources (Buitenhuis, 1993). Also improved water supply does not necessarily provide good quality water. It is for this reason that the past decade has been selected as " International Drinking Water Supply and Sanitation Decade " (IDWSSD 1981-1990), with an intention to provide safe water for all by the year 1990. During this decade an additional population of 1.3 billion new users could be provided with safe drinking water. The objective of full coverage could not be achieved within the decade and is proposed to reach the target by the year 2000 (UNDP, 1990).

In developing countries, majority of the population live in rural areas. In the Water Decade Government agencies and international organizations gave special emphasis in developing rural water supply schemes. The two main sources identified were ground water and surface water. Often the surface water is polluted. If ground water can be tapped at larger depths, in most cases it will be free of suspended solids and will have most of the desirable physical, chemical and bacteriological characteristics. Often such water can be supplied to the community without any treatment. Thus groundwater has been a proper choice of water source particularly for small communities where treatment of surface water is difficult or impossible to administer.

The possible technological options included dug wells, borewell/tubewell with handpump and pumped schemes with standposts. At a cost reduction of 60 to 80 percent, handpump based water supply can provide a wider coverage and greater reliability than that can be achieved with more sophisticated systems which offer higher levels of service (Arlosoroff et al, 1984). Handpumps installed in dugwells or borewells in areas where ground water is available provide one of the simplest and least costly methods of supplying rural population with drinking water.

Millions of people already depend on handpump for their drinking water. During the Water Decade, a large number of borewells with handpumps were installed in the rural areas of developing countries. An evaluation in India by the Department of Rural Development revealed that about 81 % water sources for domestic purposes were based on ground water (Ramasubban and Singh, 1989). In India, more than 300 million people depend on handpumps for their drinking water (GOI, 1993) and this is recognized as one of the easiest method for providing drinking water to the isolated communities and villages in rural India.

This chapter in general covers the problems and the objectives of the study. The chapter begins with the normal problems encountered in handpump water supply systems. Then it presents the specific problems encountered in Palakkad district with handpump water supply systems. Finally the chapter ends with the objectives and hypotheses of the present study.

1.1. Problems in General

Kerala combines an extremely high annual rainfall with a shortage of drinking water in many places. In some places, the availability of safe water is polluted by the behavioral practices of the people. According to the available statistics, 70% of the urban and 40%of the rural population have access to safe water supply in the state (Kurup, 1994).

Though endowed with numerous rivers and high annual rainfall, Kerala has its own problems of water scarcity. Almost 90% of the rains in an year are precipitated during the two rainy seasons *viz.* north-east and south-west monsoons within about five to six months of the year. During the summer months the salinity threshold in most of the rivers travels even up to 25 kilometres from the sea coast. In some rivers, because of the steepness of the river bed, the flow dwindles down as soon as the rains cease and during summer months the river beds completely dry up (KWA, 1988).

In the northern Kerala sources such as private wells, pond/river water, standposts and handpumps were used for drinking purposes. During dry season, most households, including those with private wells take water from public water posts if any nearby since almost all wells dry up or have very little water. Most tributaries are dry and water supply from the standposts is irregular. Handpump water is used only as a last resort. Complaints on the quality, quantity and supply of water were frequent (SEU, 1989).

In most places water is used for all purposes. Pond and well water are used for bathing and washing clothes. The preference of well water over handpump water is so high that people trek long distances to fetch atleast one container for drinking/cooking purposes. During the summer months, in some places, water is being supplied in lorries, each household being allowed to have one or two buckets of water. A notable feature is that public water post are being used only when household's own or nearby wells dry up. Intensive use of standposts is observed during the summer, which ranges from 2 to 4 months on an average per year. During wet season, typically water from the standposts is used for washing and bathing, especially if the location of the water point provides for privacy and accessibility (SEU, 1989).

The success of a handpump system depends on proper attention to six key elements on the whole system such as the community, the aquifer, the well, the maintenance system, the pump and the finance. Analysis of many schemes reveal that the majority of the handpump failures are due to inadequate arrangements for operation and maintenance system. Few failures can be attributed to the choice of the handpumps. The other prominent causes of failures are poorly constructed wells, lack of community involvement in project selection and implementation, designing for the wrong service level, siting pump in the wrong place or at the wrong depth, failure to ensure an adequate supply of spare parts supply, disregard of water quality implications (taste or corrosion) and failure to ensure funds for equipment or spares (Arlosoroff et al, 1987).

A recent evaluation say that the groundwater exploitation in the country is increasing rapidly. But the CGWB estimates indicates that the overall exploitation in the country is still below 28% of the gross resources available. Over exploitation of groundwater manifests in many ways . Particularly decrease in yield of wells, increase in drawdowns in pumping well and depletion of water levels in wells are the general effects in all the over exploited areas. Abnormal lowering of water levels has been reported from most of the hard rock areas in peninsular India. The handpump wells or pump wells used for domestic water supply, however, show tremendous decrease in yield on account of low water levels (increase in head), heavy drawdowns and sometimes even fail to give sustained supply of water on account of slow recuperation (Ghosh et al, 1995).

1.2. Problem Identification

Borewell with handpumps are one of the major sources of drinking water in the rural areas of Palakkad district. Problems seem to exist in these schemes with respect to quantity, quality and acceptance of water.

The main quality problems are

① high iron content;
② bad taste; and
③ corrosion of pump material.

Water in some of the borewells have high iron content causing bad taste, staining of clothes which may lead to rejection of the source by the people. Literature on water quality investigation shows that pump corrosion can be an important reason for iron problem in the water from handpump schemes. The effect of corrosion on handpump is two fold. First it affects the mechanical performance leading to broken pump rods and damaged pipes. Second, corrosion bi-products significantly affect water quality and thus affect the acceptance of water pumped from these schemes. The high iron concentration that results from corrosion makes water especially unacceptable to pump users because of its unpleasant taste, turbidity and side effects such as discoloring food and staining laundry (Langenegger, 1994).

As an Assistant Engineer working in Palakkad for KWA, the author was also engaged in the construction of borewell schemes. From the personal observations of author, it has been found that frequent breakdowns were occurring in the handpump schemes. People often complained about bad taste, turbidity etc. in the borewell water. The presence of iron was evident from the stained platforms. Apart from the above reasons, the distance /location of the well may also be one of the reasons for the non use of the handpump and subsequent use of unprotected traditional sources. UNICEF has identified the distance to the borewell as the single largest cause for general non-use and the combined effect of distance and poor taste forced the people to use borewell schemes for purposes other than drinking (UNICEF, 1989).

In certain cases the discharge of the borewells are not sufficient to meet the demand. People may have to allow certain recuperation time before a second bucket can be withdrawn. Thus inadequate quantity is also one of the contributing factors for the reduced acceptance level.

It has been stated that " Breakdowns that force people to use contaminated water, for only two per cent of the time, risk undoing the health benefits of drinking clean water during the rest of the year". Thus for continued functioning and use, limitation of breakdowns and quick repair are essential (van Wijk-Sijbesma, 1985). Against this background it was very important to investigate the functioning, use and acceptance of borewell schemes in Palakkad district.

1.3. Objectives

The present study relates to the problems encountered with the handpump schemes in the rural areas of Palakkad district. The objectives of this study are

① to evaluate the performance of handpump schemes with regard to functioning;
② to evaluate the performance of handpump schemes with regard to water use;
③ to obtain an in-sight into the water quality of handpump schemes in Palakkad;
④ to suggest possibilities to improve the performance of these schemes in Palakkad.

Stated otherwise, the objective of the study as follows;

To investigate the reasons why majority of the handpumps in Palakkad district are not used for drinking purpose and why they are poorly functioning:

1.4. Hypotheses

The possible hypotheses for poor functioning and non-use of handpump systems are given below in two sub-sections.

1.4.1. Functioning of Handpumps

The functioning of a handpump system depends on the following parameters.

① *pump discharge*
Poor pump may affect the functioning of handpump systems. In order to investigate this issue, discharge of each handpump is measured in the field tests.

② *leakage*
This may affect the functioning and the same has been measured in the field for each handpumps.

③ *breakdown frequency*
Breakdown frequency may also affect the functioning of handpump systems. This has been collected from the field interviews.

④ *average downtime*
The functioning of a handpump system may depend on the downtime. The average downtime on each handpump is also collected from the field interviews.

⑤ *broken and badly constructed platforms*
Broken and badly constructed platforms may have an impact on the functioning of handpump systems. this parameter is observed in the field.

⑥ *water quality*
Poor water quality such as low pH which can cause corrosion of pump materials which in turn affect the functioning of handpump systems. In order to investigate this issue, the water samples from each handpump are collected and tested for pH in the laboratory.

⑦ *maintenance system*
Eventhough this affects the functioning of a handpump severely, this indicator has not been covered in the present study due to limited time for data collection.

1.4.2. Use of Handpumps

The water use from a handpump system may depend on the following parameters

① *number of persons using the handpump*
The number of persons using the handpump may have an effect on the user acceptance of handpump systems. In order to examine this issue, the average number of persons using the handpump has been collected during the field interviews.

② *volume of water collected per capita per day*
This parameter may affect the user acceptance. The questionnaire for the field interview has been prepared in such way as to get the required information from the interviews.

③ *distance of handpump from the household*
This parameter is obtained from the water resource maps, prepared for each handpump location, which included the interviewed households.

④ *presence of alternative water sources*
The presence of alternative water sources may have an effect on the user acceptance. In order to investigate this issue, a water resource map is prepared and the sufficient data is obtained from it.

⑤ *water quality*
Water quality parameters such as turbidity, iron content, hardness, chloride etc. are tested for each water samples in the laboratory.

⑥ *pump environment*
Bad pump environment such as broken platforms, broken drains, stagnant pools of water near by etc. may affect the user acceptance badly and the same indicators are observed in the field.

⑦ *condition of pump*
Poor condition of pump may affect the user acceptability and this has been observed in the field.

1.5. Relevance

In rural areas of Kerala, water sources are used for a combination of domestic and productive purposes. Apart from drinking, the water use includes preparation of foods, washing of clothes, bathing, livestock feeding, vegetable growing *etc.*. Often the amount of water used for domestic purpose increases when the water supply improves. Change in taste and quantity problems may make people to reject handpump and as even a short period in which a handpump does not function will force many people to return to traditional water sources, with associated health risks.

There is a large area of public ignorance about how health is affected by unsafe drinking water. In the absence of factual knowledge, misconceptions and vague guesses are use to explain the relationship between health and drinking water. Across the states in India, about 88 to 95 percent of the people believe that bad drinking water causes health problems, but majority doesn't know bad water cause which diseases (Ghosh et al, 1995).

More than 80% of the diseases in developing countries are due to poor quality of drinking water. As mentioned earlier, handpump systems are still the cheapest method for providing protected water to the rural masses. But, if people continue to use the traditional sources again for drinking and if these sources are polluted, then the associated health risks are much higher. At the first instance, the purpose of the handpump project is defeated. This not only means a loss of investment, but also hampers the attainment of health and other developmental benefits (van Wijk-Sijbesma, 1985). Hence to improve the system and to utilize the scarce resources effectively, a study on the use and functioning of handpumps was essential and this may help the planners and decision makers for arriving at appropriate solutions.

1.6. Structure of the Report

The report consists of a total of seven chapters. The second chapter discusses about the administrative structure of the Government in India and Kerala and their development of rural water supply programmes. The third chapter reviews the literature on handpump water supplies and the general indicators affecting the functioning and use of handpump water supplies. The chapter four discusses the methodology adopted in the present study. The fifth chapter reviews the results obtained and the sixth discusses the results in relation to the functioning and use of handpumps. Finally the seventh chapter presents the conclusions and recommendations of the study.

Chapter 2

Rural water supply in India and Kerala

This chapter provides an overview of the general features of India, Kerala and their development of rural water supply sectors. The chapter starts with a short description about India, which includes general features, its administrative set up of Government and its water resources potential and utilisation. The further section deals with the features of Kerala State which provides information on population, settlement pattern, water utilisation, geography, climate etc. The chapter then presents the history of development of rural water supply sector in India and the activities covered under Rajiv Gandhi National Drinking Water Mission (RGNDWM). It then shortly covers the development and activities of rural water supply programmes in Kerala. Finally it concludes with the background of the selection of the district under the present study.

2.1. India

India, the largest democratic country in the world has a geographical area of about 3.3 million square kilometres, measures 3200 km from the north to south and 3000 km from the west to east. The following sections deal with the general features of the country.

2.1.1. General Features

India is the second largest populous country in the world after China. In 1991, India's population figured at 846.3 millions. The average annual population growth rate during the last decade was 2.1%. Seventy five per cent of the population live in rural areas, but much of the increase has been concentrated in urban areas. India's urban population increased from 19 to 27% of the total population between 1965 and 1990. Urbanisation is reflected in the existence of more than 20 cities with over one million residents. Most prominent among these are : Bombay (12.6 million), Calcutta (10.9 million), Delhi (8.4 million), Madras (5.4 million), Hyderabad (4.3 million), and Bangalore (4.1 million) (Economic Review, 1994).

The country's economical and social conditions, languages, cultural and religious tradition also show wide variation. While most Indians subscribe to the Hindu Religion (83% approximately), there are large Muslims (11%), Christians (3%), Sikhs (2%), Buddhists (1%) and minorities in addition to other significant grouping such as Parsees and Jains.

According to 1991 data, some 43% of India's total area is agricultural land while 20% is forested. Physiographically India can be divided into seven divisions. These are : (1) the northern mountains, (2) the great plains, (3) the central highlands, (4) the peninsular plateau, (5) the east coast belt, (6) the west coast belt, and (7) the islands (Ghosh et al, 1995). The country has varied climatic zones with considerable regional differences, including well irrigated areas in the northwest, the deserts in the west, the Himalayas in the north, the hill tracts in the east, the

Gangetic plain, the semi-arid Deccan plateau and the tropical coastal areas in the south.

The Worldbank estimated that at the end of the 1980s, about 40% of the population (about 340 million people) lived below poverty line, defined during the Seventh Five Year Plan period 1985-1990 as household income of Rs. 6400 per year or about US$ 460. A GDP per capita of US$ 350 together with a life expectancy of 59 years and an average of 2.4 years of schooling with an adult literacy rate of 48%, classified India by the UNDP in a 'low human development' country in 1990 (Economic Review, 1994).

Although India is a poor country, it is a major industrial power, ranking among top 20 in the world (in 1990, manufacturing output was more than US$ 48,000 million). The shares of the three major economic sectors are roughly : agriculture 30%, industry 30% and services 40%. For the past few years, the agriculture production has improved much, thanks to the timely and healthy South-West monsoon. India is well advanced in the fields of defence and space technology. India is the fifth country in the world to have its own remote sensing satellites. India also has large electronics and petrochemical industries, the product of which earns foreign exchange to the country (Economic Review, 1994).

In spite of such economic achievements, which brought prosperity to the roughly 150 millions member of Indian middle class, it has become painfully obvious that for many millions, poverty tends to increase. Due to population pressure and inequitable distribution of assets, the gap between the richest and the poorest has widened (Economic Review, 1994).

2.1.2. Organisation of Government

India consists of 25 states and 7 union territories (UTs). The constitution of India provides two tier system of Governments, one at the centre and the other at the state level. India, the largest democracy in the world has a federal system of Government at the centre, with two houses of parliament : the lower house or the "*Lok Sabha*"(545 seats), elected directly and the upper house or the "*Rajya Sabha*"(245 seats), elected indirectly by the state assemblies. The constitutional head of the government is the president who is elected by the members of the parliament and the state legislative assemblies. A nominee of the parties who has majority in the Lok Sabha is appointed as the prime minister by the president. The prime minister is assisted by a council of ministers, collectively called the *cabinet.*

The states have democratically elected legislative assemblies. The head of the state is the Governor, appointed by the President of India. The governor appoints the nominee of the political parties who have a majority in the state legislative assembly as the chief minister. The chief minister is helped by a council of ministers.

The union territories are ruled directly by the Central Government through an administrator, who is called a Lieutenant Governor, appointed by the President of the country on the advise of the cabinet.

The constitution divides all powers and control over public activities into three lists : the union, the state and the concurrent list. The first contains some 97 subjects of predominantly national importance such as foreign affairs, defence *etc.*, the second enumerates 66 subjects such as police, public health, education, agriculture, irrigation, rural water supply and sanitation *etc.*,where the state has full authority to legislate on application within the state: and the third involves 47 items over which the centre and state have concurrent jurisdiction (though central law will prevail incase of conflict) (Economic Review, 1994).

2.1.3. Water Resources and its Utilisation in India

Precipitation (snow and/or rainfall) is in general the sole and thus, the most important source for the replenishment of the water resources in India. The rainfall over the country is quite abundant. The variation in distribution of rainfall with space and time, due to prevailing meteorological conditions and also topography of the area is so great, that while some region experience floods, some others reel under drought at the same time. On an average, annually about 112 cm rainfall is received over the plains of India. The South-West monsoon, which sets in around 1st June over Kerala and covers the whole country by about 15 July, contributes more than 75% of the rainfall in the country except in some regions in South which have their major contribution during its retreating period (October-December) popularly termed as the North-East monsoon season.

Surface water and ground water are the major two sources of water in India. Surface water, mainly contributed by the rivers, is the major water resource in the country accounting for more than 60% of its water potential. The river system of India can be classified into four groups viz.(I) Himalayan rivers ; formed by melting of snow, (ii) Deccan rivers : mostly rain fed, fluctuate in volume, (iii) costal rivers : short in length, limited catchment, and (iv) rivers of the inland drainage basin with an ephemeral character (Ghosh et al, 1995).

The major ground water source in the country are borewells. In addition to borewells, millions of dugwells are constructed in different parts of the country to meet the domestic and irrigation demands. A study conducted by the Central Water Commission (CWC) revealed that at the end of the Vth Five Year Plan, there were about 8.7 million irrigation dugwells, 3.36 million private tubewells and 0.046 million State tubewells in the country (Ghosh et al, 1995).

Preliminary studies conducted in the river systems in India indicates that the total utilisable surface water resources of the country is approximately 670,000 Million Cubic Metres (MCM). Study conducted by the CWC reports that the ground water recharge of the country comes to about 430,000 MCM and hence the total utilisable water comes to about 1100,000 MCM. In 1985, India used 50% of the total utilisable water, which corresponds to 13% of annual rainfall (Ghosh et al, 1995).

2.2. Kerala State

Sandwiched between the Western Ghats on the east, and the Arabian Sea on the west, Kerala is one of the most beautiful States in India. A tropical paradise of waving palms and wide sandy beaches, this thin strip of coastal territory slopes down from the mountain ghats in a cascade of lush green vegetation.

2.2.1. History

The history of Kerala and its Malabar coast is closely linked with its commerce and trade. The geographical position of Kerala has also contributed to its commercial and economic prosperity. The fame of Kerala spices brought the Romans in 30 AD., who were followed soon after by the Greeks, the Arabs and the Chinese.

Till the beginning of the eleventh Century, the people of Kerala and their eastern neighbours, the Tamils shared a common culture and language. In 1120 AD., constant political feuds broke Kerala into many petty kingdoms, which were then ruled by the Tampurans. During the second half of the 12th century, the people of Kerala joined to form a distinctive culture of their own, adopting Malayalam as the main language.

The Tampurans were succeeded by the Zamorin of Kozhikkode (a city in the north Kerala), during whose regime, the Portuguese set foot in Kerala. The Dutch, the French and the English followed. Known as the Malabar Coast and Cochin-Travencore, Kerala experienced both prosperity and strife under the British rule. Kerala contributed a lot to the nation during the formative years of modern India. Nine years after the Independence in 1956, the present state of Kerala was formed, comprising the Malayalam speaking tracts of Southern India (Poovendran, 1996).

2.2.2. Population and Settlement Pattern

Kerala derives its name from 'Keram', the coconut palm. Keralam is the land of coconut. It has an area of 38,863 square kilometres, about 1.27% of the total surface area of India. The width of the State varies from 35 to 120 km, with an average of about 65 kilometres. According to 1991 census, the population of Kerala is 29.09 millions which comes to about 3.7% of the total Indian population. The population density of the State was 749 per square kilometres in 1991. The sex ratio was 1036 females per 1000 males in 1991. Since 1971, the growth rate has shown a decreasing trend and the present growth rate[1] of 14.32 during the last decade is the lowest among the Indian states, with an annual exponential growth rate of 1.34.

Kerala is a land of genuine religious secularism, with a rich culture renowned the world over. Majority of the Keralites belong to the Hindu Religion (60%) with large Muslims (20%) and Christians(20%).

Settlement pattern gives an even distribution in towns and villages over the entire state. The variations between urban and rural areas in density of population, economic disparity, attitudes *etc.* are little in such a way that it is very difficult to distinguish between a village and a town.

[1] growth rate - percentage of increase in population in 1991 when compared with the population in 1981

The dwellings are almost evenly spread out in the villages and the hamlet pattern of living is not prevalent in the state. The standard of living of rural people of Kerala are not much different than that of the urban population. From the pattern of distribution of the dwellings and the standard of living of the people, it is difficult to say where the town ends and where the village begins (Kurup et al, 1996).

2.2.3. Geography and Climate

Flanked by the Karnataka State on the north and the Tamil Nadu in the east, Kerala is a pleasant strip of land, between the Arabian sea and the Western Ghats. Based on the elevation and physical features, the state can be divided into three regions, namely - *the sandy coastal regions(the plains)* with its extensive coconut groves, paddy fields, backwaters and sea, *the midland regions* made up of fertile reddish hills and valleys that grow the most of Kerala's agricultural crops and *highlands* include peaks, extensive ridges and ravines of the Western Ghats, where sandal wood, tea , coffee, rubber and most of Kerala's exotic spices are grown.

Kerala enjoys a good whether almost all through the year. It is neither too cold in the winter months nor too hot in summer. The mean maximum temperature is 32^{0}C, with a variation of 2^{0}C. The Western Ghats which form a solid, continuous mountain wall, seem to dominate the topography of Kerala. This ghat act as a natural barrier during the South-West Monsoon.

2.2.4. Water Resources and its Utilisation in Kerala

Kerala is a land of rivers and backwaters. Forty four rivers, forty-one flowing west and three flowing east, cut across Kerala with their innumerable tributaries and branches But these rivers are comparatively small, and are entirely monsoon-fed, most turn into rivulets in summer. There are significant backwater areas along the coast. Much of Kerala's cost and plains has a high ground water table. The state receives a good annual rainfall, which varies from 125 to 500 cm with an average of 308.5 cm.

Much of Kerala's ground water is obtained from dugwells. Kerala has the highest density of dugwell population in the world. Investigations by Centre for Water Resources Development and Management (CWRDM) indicate that there are about three million dug wells in the state, with an average density of 250, 150 and 25 wells per square kilometre in the coastal, midland and high land areas of the state respectively. The normal range of these values are 200 to 300 in coastal belt, 100 to 200 in the midlands and 0 to 50 in the high ranges (SEU, 1989).

A preliminary study conducted by CWRDM reports that the utilisable ground water potential of the State is of the order of 4000 MCM. The three million dugwells in the State extracts about 1650 MCM of water annually. The physical survey by CWRDM also reveal that on an average, around 1500 litres of ground water is being extracted per day from each dugwells. Over and above the traditional open dugwells, State has also around 7700 borewells and tubewells which extracts another 80 MCM. This means total ground water withdrawal from the state is of the order of 1730 MCM per year against the utilisable annual recharge of 4000 MCM (SEU, 1989).

2.2.5. Physical Infrastructure

After the State's reorganization in 1956 social services reached fairly high standards. Subsequently the governments started adopting several measures for the upliftment of the society and economically disadvantages classes including, successful land reform and rapid expansion of education and health services. During the first democratic legislative assembly elections in 1957, the first democratically elected communist government in India and perhaps in the world, came to power in Kerala.

Kerala has a total road length of 139,000 kms and 1189 kms of railway line. Almost all village centres and panchayaths are accessible by roads. There are three air ports in the State. Kerala has a major sea port and a few minor ports (Economic Review, 1994). The department of telecom has established its roots even in the remotest parts of the state.

Kerala is noted for the early development of its health and education services. The religious diversity and tolerance of its people is commendable. Historically Kerala has been a pioneering state in the development programmes literacy, health care, land reform, emancipation of woman, sanitation and family welfare.

The state have an extensive network of educational institutions including 6702 primary schools, 2929 upper primary schools, 2475 high schools, 174 arts and science colleges, 39 polytechnics, 39 technical schools, 12 engineering colleges, 2 dental colleges, 5 Ayurveda medical colleges, 5 Homeopathic medical colleges and 6 Allopathy medical colleges.

Kerala achieved total literacy in 1992. The health infrastructure of Kerala is best among the Indian States. Life expectancy at birth increased from 45 years in 1951-1961 to 70 years in 1991, with 69 for men and 72 for women. The birth rate is 17 and death rate is 6 per 1000. Infant mortality rate in Kerala is 13 per 1000 (Economic review, 1994). Although mortality is low, morbidity rates are high and water and sanitation-related diseases feature prominently, despite relatively high levels of improved water supply and sanitation.

Possible reasons for the relatively high morbidity figure are :

① Disease reporting in Kerala is high, because of good network of clinics and PHCs[2](one per 5000 inhabitants);

② Keralites perceive such diseases as serious and will seek help from the Government health facilities rather than from traditional health care establishments;

③ Coverage and quality of performance and use of water supply and sanitation facilities are not yet high to have a health impact (source : Kurup et al, 1996).

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[2]PHCs - Primary Health Centres - these are the institutions under the Ministry of Health, responsible for medical treatment and conducting health awareness programmes at the village level

Although it can be argued that the high morbidity figures are the product of a high density of services and reporting of disease, these two explanations alone cannot account for the illness levels of Kerala. Nearly all people are literate, and have access to information about the illness and diseases. This probably serves to inflate the reported morbidity figures, but what is being inflated is nonetheless a substantial burden of illness. The high morbidity may also in part be a function of decreasing mortality and the greater proportion of the older people. This is attributable to lower death rates combined with better child care for the newly born (Kurup et al, 1996).

2.2.6. Administrative Setup of the State

The state has a democratically elected Government which can rule the state for five years. A chief minister and a counsel of ministers, are in charge of the various departments of the government. The seat of the Government is located in the capital city of the state, the Thiruvananthapuram.

State government functions are further divided among various departments and agencies. The major departments are Revenue, Public Works, Health Services, Irrigation, Agriculture, Rural Development, Police, Panchayaths, and Municipalities and agencies like Kerala Water Authority, Kerala State Electricity Board *etc*. Each major department is headed by a secretary (usually an officer of the Indian Administrative Services).

For administration of revenue and law and order, the state is territorially divided into 14 revenue districts. These revenue districts are further divided into Revenue Divisions, then to Taluks and finally to Villages. The district administration is headed by the district collector (also an IAS officer), revenue division by revenue divisional officer, Taluks by Tahsildars and villages by village officers, all are government servants.

Rural and Community Development activities are administered by Rural Development Department. Accordingly the whole state is divided into 14 District Panchayaths. They are further divided into 151 Block Panchayaths, again sub-divided into 990 Grama Panchayaths. This three tier system is popularly known as '*Panchayath Raj System*'. Each of these bodies have democratically elected members, and in effect they are local self governments, which has the power to carry out most of the rural development works including agriculture, road works, irrigation *etc*. Each Panchayath is again divided into about ten wards, each of whose population averages about 3000 people. Local government at Panchayath level consists of an elected Panchayath president and a council of elected ward members (one member per ward). The figure 1.1 shows the State-wide set up of two different departments.

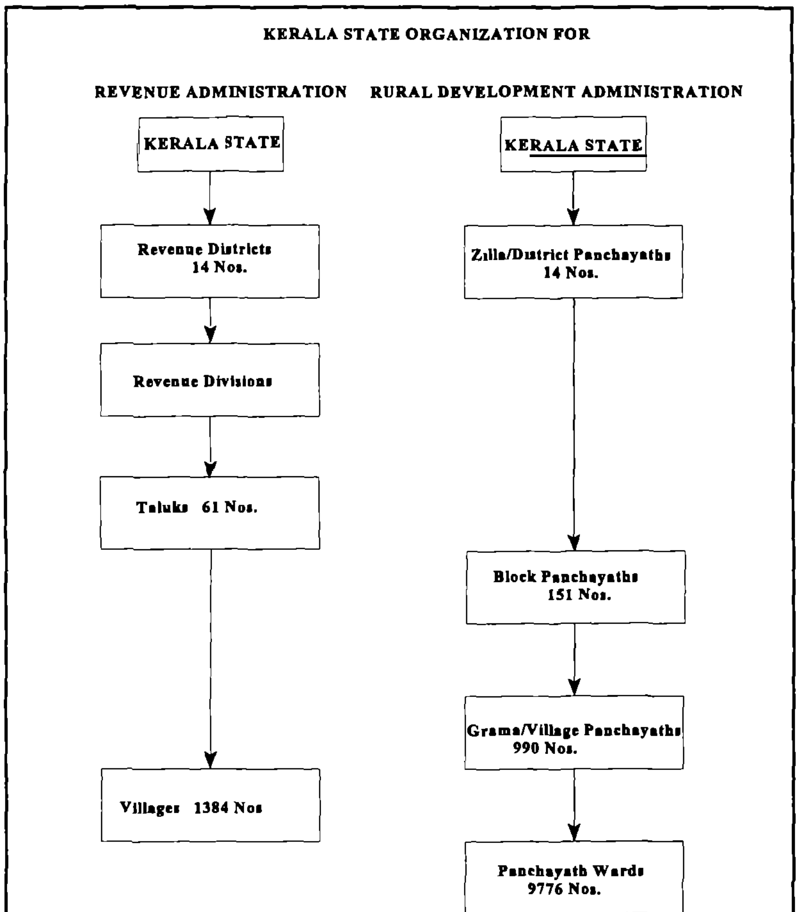


figure 1.1 Kerala State Set up of two major departments

2.3. Development of Rural Water Sector in Modern India

The Bhore committee, appointed in the pre-independence era (1944) was the first body to draw attention to the importance of safe drinking water supply on a nation wide scale. It assumed importance in National Development plans. Subsequently the provincial governments came out with proposals , but with far reaching results (Ghosh et al, 1995).

The Environmental Hygiene Committee (1948-49) appointed by the Union Government was the first agency of its type charged with an overall assessment of the country-wide problems in the entire field of Environmental Hygiene. The recommendation of the committee included a comprehensive plan to provide water supply and sanitation facilities for 90% of the population within a period of 40 years. However, as late in 1961, the National Water and Sanitation Committee, appointed by the Union Ministry of Health has noted in its report that no concerted measures were taken to implement the recommendations of the Environmental Hygiene Committee (Ghosh et al, 1995).

With the implementation of Five Year Plans in India, top priority was given for Rural Water

Supply Schemes. Right from the commencement of First Five Year Plan, the provision of drinking water supply in rural areas was the responsibility of the States and funds were provided in the State budgets. National water supply and sanitation programmes was introduced in social welfare sector in 1954. The States gradually constituted PHEDs for constructing and managing water supply and sanitation installations. It was observed in 1960 that rural water supply projects were implemented only in those villages which were easily accessible. Hence the Government of India(GOI) requested the states to identify those villages which were neglected in the past and shall have to be covered in the successive Five Year Plans (GOI , 1993).

Taking into account the magnitude of the problem and to accelerate the pace of coverage of those villages, the GOI introduced the Accelerated Rural Water Supply Programme (ARWSP) in 1972-73 with 100 % grants in aid to assist the States and Union Territories to implement the schemes in such villages. This programme continued till 1973-74 and with the introduction of Minimum Needs Programme (MNP), it was withdrawn. Later it was reintroduced in 1977-78 when the progress of supply of safe drinking water to identified villages was found to be well below expectation (GOI, 1993).

In the year 1977 the United Nations Water Conference separated the issue of drinking water and sanitation from other water issues to stress the seriousness and magnitude of the problem of drinking water. Being a signatory in the conference India was committed to achieve the target by 1991. The water Decade Programme in India was accordingly launched on 1 st April, 1981 to achieve definite targets of coverage of entire population by 31st March, 1991(GOI, 1993).

The strategy in India during the Water Decade has been to concentrate first on the problem villages. These were identified as the villages which didn't have assured sources of water within a distance of 1.6 kms or within a depth of 15 meters (or hilly areas where water sources were available at an elevation difference of more than 120 meters from the habitation) or where the available water suffered from either chemical (fluoride, iron, brackishness and other toxic elements) or biological contamination (guinea worm, cholera, typhoid) (Ramasubban and Singh, 1989). Recently the norm with respect to distance has been revised to 0.5 kms and a basic service defined as a handpump/standpost serving a population of 150, at a distance of 250 meters horizontally and 15 meters vertically from the habitation. Altogether 231,000 villages were identified as problem villages to be covered with safe water supply in the water decade.

Of the 231,000 identified problem villages, 192,000 were covered in the Sixth Plan. The programmes for covering the balance of 39,000 villages were proposed in the Seventh Plan. During the Seventh Plan, it was also decided to give priority for coverage of Scheduled Caste (SC) / Scheduled Tribe (ST) habitations and for this purpose funds were earmarked under ARWSP in the same proportion as was being done under the State Sector Minimum Needs Programme (MNP) for SCs under Special Component Plan and for STs under the Tribal Sub Plan.

In August 1985 the subject of rural water supply and sanitation was transferred from Ministry of Urban Development to Department of Rural Development with the objective of securing implementation of the programme and their integration with other rural development programmes. The National Drinking Water Mission was launched as one of the societal Missions in the year 1986. Later it has been renamed as Rajiv Gandhi National Drinking Water Mission (RGNDWM). GOI continues to give highest priority to rural water sector through the activities of the Mission and ARWSP (GOI, 1993). The Activities of RGNDWM are discussed in detail in the following section.

The approach to the rural water supply sector during the two annual plans remained same as in the Seventh Plan. At the end of this period, about 3000 hardcore no source problem villages were remained without any safe drinking water supply.

Highest priority was given in the Eighth Five Year Plan for the coverage of these three thousand villages by the end of March, 1993. Steps were also taken to increase the supply level to 40 lpcd in the partially covered villages in the country. During the Eight Plan, efforts were also made to achieve zero incidence of guineaworm infection by 1993 and its total eradication by the year 1995.

2.4. Rajiv Gandhi National Drinking Water Mission (RGNDWM)

This Mission, under the Ministry of Rural Development, Government of India has to look after the Water Supply Programmes in villages and related Water Management issues.

The Mission was launched with the following objectives

① to cover all no source problem habitations
② to supply 40 litres per capita in all areas for human beings and additional 30 litres per capita in desert areas for cattle, within accessible reach
③ to evolve cost effective appropriate technology to solve specific problems
④ to take conservation measures for sustained supply of water
⑤ to improve conservation measures for sustained supply of water
⑥ to improve performance and cost effectiveness of ongoing programmes
⑦ to create awareness on use of safe drinking water
⑧ to promote community participation

The activities of RGNDWM includes Mini-Mission Projects and Sub-Mission Projects.

2.4.1. Norms

RGNDWM has adopted the following norms for providing safe drinking water to rural population in the villages.

① 40 litres of drinking water per capita per day for human beings.
② Additional 30 litres per capita per day for cattle in desert districts.
③ One handpump or standpost for every 250 persons.
④ Water sources should exist within 1.6 km in the plains and within 100 metres elevation difference in hilly areas.

⑤ Water is defined as safe if it is free from biological contamination (guineaworm and bacilli causing diseases like cholera, typhoid *etc.*) and chemical contamination (excess fluoride, brackishness, excess iron, arsenic, nitrates *etc.*)

2.4.2. Priority

The following priorities have been adopted to cover those difficult areas which were not covered earlier

① to cover Sixth Plan spill over problem villages.
② to cover all villages with no water source
③ to cover no source problem villages surveyed or identified subsequently
④ to cover all villages with contaminated drinking water (both chemical and biological)
⑤ to cover all villages with per capita supply less than 40 litres to bring the service level to the norm level
⑥ to cover hamlets and habitations

2.4.3. Mini-Mission Projects

The concept of Mini-Mission is a district-based integrated project covering major aspects of rural water supply to attain sustainable water supply on long term basis with close involvement of community and NGOs in the implementation, O&M and health education and solution of specific problems of excess fluoride, iron, brackishness *etc.* It aims at adopting appropriate technology and such other techno-scientific inputs as scientific source finding by satellite imaginary *etc.* for sustainable and safe water supply. Mini-Mission Projects were taken up in the fifty-five Mini-Mission districts, were selected to demonstrate an integrated model, making use of coordinated efforts to solve quantitative and qualitative problems and their subsequent replication in other parts of the country. The entire programme was funded by the GOI (GOI, 1993).

Mini-Mission projects were taken up in the entire State of Goa and UTs of Andaman and Nicobar Islands, Lakshadweep and Pondicherry, besides 51 districts in the remaining 24 States. The entire programme was funded by Government of India (GOI). Palakkad was one among the fifty five Mini-Mission districts (GOI, 1993).

2.4.4. Sub-Mission Projects

RGNDWM recognised the need to concentrate on certain peculiar problems which were area-specific and at the same time, needed to be tackled on a national scale because each of these problems existed in several States. The following Sub-Mission areas where identified and nodal collaborating agencies were selected to look at these problems and to work, towards eradication or other solutions on a scientific basis.

(1) Guineaworm Eradication

The guineaworm eradication has been an important activity of RGNDWM. The Mission played a vital role in providing safe water including conversion of unsafe water sources into safe ones in guineaworm affected villages and chemical treatment of the source by Temephos or Chlorine.

(2) Defluoridation Activities

Certain areas have reported presence of fluoride in excess in drinking water and consequent contamination of the same which has resulted into endemic fluorosis in those areas, manifesting into dental and skeletal fluorosis in human beings. RGNDWM has taken a comprehensive programme of not only creating awareness about fluorosis but also to treat that water, make it potable and bring down the fluoride content within the permissible limit of 1.5 ppm. The Mission has sanctioned 106 Fill and Draw type and 377 handpump attached types of Defluoridation plants out of which 58 Fill & Draw and 345 Handpump Attached type have already been commissioned as on 30.9.1994.

(3) Removal Excess Iron

The control measures taken are
(a) Supply water within permissible limit (1.0 ppm) by providing alternative sources ; or to
(b) Supply water after treatment

The problem is prevalent in 15 States and the UT of Pondicherry. The Mission had approved setting up of 11908 iron removal plants. More than 8800 plants have been commissioned in the 15 states and UT of Pondicherry.

(4) Control of Brackishness

Control measures include supply of water with total dissolved solids within permissible limits (1500 ppm) either by providing alternate sources or supplying water after desalination. The excess salinity is prevalent in 12 states which includes Haryana, Madhya Pradesh, Punjab and Rajestan apart from the coastal states and in 3 UTs. 163 desalination plants were approved by the Mission, 143 have been commissioned till March 1994.

(5) Conservation of Water

To increase the water retaining capacity of the soil and to bridge the gap between availability of ground water and its water demand, traditional and non-conventional methods have been adopted. One of the methods adopted was cascade terracing on hilly areas supplemented by moisture retaining plants on the borders of the terraces .the Mission has been active in promoting both orthodox and innovative methods of conservation of water including the construction of water harvesting structures such as check dams, sub-surface dams, barriers, injection wells *etc.*

2.4.5. Water Quality Testing Laboratories

The Mission has been concerned about the various type of contamination of drinking water, particularly chemical contamination. The Mission has approved 200 stationary laboratories and aims to cover in due coarse in each district with one such laboratory. The Mission has also sanctioned 26 mobile testing laboratories out of which 22 have been already been fabricated and put to use.

2.4.6. Solar Photo Voltaic Pumping Systems

Some of the rural areas in India do not have electricity facilities for motor pumpsets. Even if electricity is present, it is not reliable on account of intermittent supply. The solution to this problem comes from the Solar Photo Voltaic (SPV) Pumping System by tapping solar energy by cells exposed to the sunlight which is converted into electricity for lifting water from great depths. The Mission has already sanctioned a total of 142 SPV systems, out of which 125 have already been installed till 30.9.94 (source : Ghosh et al, 1995).

2.5. Rural Water Supply in Kerala

Prior to the inception of Rural water Supply schemes, the Rural population of Kerala was primarily depending on supply of water from dugwells, ponds, rivers *etc.* for their various water requirements. Very little attention was given to provide safe drinking water for the rural population in the pre-independence period. However it received attention only after the introduction of the National Water Supply and Sanitation Programme in 1955.

With the implementation of Five Year Plans in India, along with other Social welfare Schemes, Rural Water Supply was given top priority. The State Government started various rural water supply schemes with Central assistance from the beginning of the second Five Year Plan. The Public Health Engineering Department was formed by the State Government in 1956 to implement various Water Supply and Sanitation Schemes in the State. In the early stages, the Rural Water Supply Schemes were executed with State and Central Funds, later assistance from Institutional financing agencies like Life Insurance Corporation and external agencies like World bank *etc.* were obtained.

In the year 1984, the Kerala Public Health Engineering Department was converted to Kerala Water and Waste Water Authority(KW&WWA), an autonomous body, for raising more resources and speedy implementation of Water and Sanitation Schemes in the State. Later it was renamed as Kerala Water Authority (KWA) in 1986.

The Kerala Water Authority is entrusted with the provision of safe water, specifically piped water, for the entire state. It is an autonomous organization in charge of design, construction and maintenance of all rural and urban piped water schemes and piped sewerage networks in the state. At present KWA maintains 1850 water schemes of varying sizes, although the majority of these are quite small.

The governments of The Netherlands and Denmark have been assisting the Kerala Water Authority financially in the implementation of drinking water supply schemes since 1980s. Indo-Dutch cooperation in the rural water sector was initiated in 1980 and Indo-Danish cooperation started in 1986 (Kurup et al, 1996).

In Kerala, socio-economic activities in rural water supply are included only in the bilaterally supported water supply schemes. For this purpose, Socio-Economic Units (SEUs) were established in the late 1980s by the Dutch and Danish Governments. There are three Socio-Economic Units, each located in the south, central and northern parts of the state. Each SEU serves on average of 20 Panchayaths, that is a population between 400,000 and 1,000,000 people. The SEUs are responsible for a wider range of water-related education and sanitation activities (Kurup et al, 1996).

2.6. Background for the selection of the District under study

As mentioned earlier, many people use borewells with handpump as their water source in India. Handpump was taken to be the most easy method of water supply in covering the major population of the country within a short time. This technology was popular in the north-Kerala and particularly in the Palakkad district. A major portion of the district lies in the highland region of the state with an overburden thickness ranging from 0 to 20 metres. Borewell with handpump has become one of the easy methods in covering the rural areas of Palakkad within a short time, especially in the drought seasons, in a cost effective manner. The author was also engaged in the rural water supply programmes in the district under KWA. This helped in obtaining the data required for the present study. The following sub-sections describes the area under study including rural water supply activities undertaken by various agencies.

2.6.1. Description of the area

Palakkad is one of the 14 districts of Kerala. It is the second largest district with an area of 4480 sq. km. The population as per 1991 census is 23,82,235. The literacy rate is 81.3%. As per Rural Development Department, the district is divided into 12 Block Panchayaths for administrative purposes. These Block Panchayaths are again divided into about 89 Grama Panchayaths. The Grama Panchayath is the institution responsible for implementing the development projects at village level.

The average annual rainfall in the district is about 200 cm. The whole district comes under the physiographic classification of midland and high land regions. The typical geologic section encountered here comprises of an overburden underlain by hard rocks. The overburden consists of laterite, lithomargic clay and weathered rock zones. The hard rocks are fractured at places in an irregular pattern with the fractures themselves linked mostly to weathered rocks. Such fractures are basically weak zones in the hard rocks. Groundwater occurs both in the overburden and in the fractures. Another major source of groundwater in this area is the sand beds of the rivers draining through the region (Rajagopalan, 1988).

One of the earlier methods of tapping groundwater was by digging well in the top soil. Hand dug wells tapping the groundwater in the top laterite aquifers have been traditional sources of groundwater supply in this area. The yield from these wells can be increased by perforating this wells into the weathered zones. But due to the low transmitting properties of the overburden, the practice was to construct large diameter wells to collect more water for meeting the peak hour demands.

The second method of extracting groundwater was through drilling borewells and fitting them with handpumps. Borewells were used to tap the water available in the fractured rock aquifers. The fractured rock aquifer systems are not regional in scale and in fact are extremely localised. Consequently identifying suitable sites where drilling can be undertaken to tap the fractured horizons pose major problems.

It is estimated that the total water potential of surface and ground water sources in Palakkad comes to about 3600 MCM and 900 MCM per year (on the assumption that 40% of annual rainfall to run-off and 10% for ground water recharge) respectively. The net utilisable ground water in Palakkad is calculated at 450 MCM per year. A preliminary study conducted by CWRDM revealed that the utilisation of surface water and the ground water in the district was about 1500 MCM and 150 MCM respectively (Rajagopalan, 1988).

2.6.2. Water Supply in Palakkad

The activities of rural water supply in Palakkad are mainly covered by two agencies : (1) under KWA and (2) under RGNDWM. Apart from these agencies, some minor works were carried out by the Block Panchayaths, CWRDM and State Ground Water Department, for which the significance in the present study is minor and hence not covered below.

(1) Activities under RGNDWM

The Palakkad District is the most drought prone district in the State and also one of the most economically backward districts in the State. Hence for these reasons, this district has been selected by the Government of India for implementation of the Mini-Mission Project, named the Technology Mission under RGNDWM for intensive coverage of water supply facilities. Rivers, open wells, streams *etc.* get dried up during summer. However the groundwater potential is fairly good and it has been proposed to provide borewells with handpumps as a first step (KWA, 1993).

The following activities were covered under the Mini-Mission Project. A Detailed Project Report(DPR) for covering all villages in the Mini-Mission district has been submitted to the Mission Director, GOI. The report included construction of 1850 borewells, energisation of borewells having good yield, construction of rain water harvesting structures such as check dams, subsurface dams *etc.* and proposal for establishing a water quality testing laboratory at Palakkad. Detailed proposals for the construction of five sub-surface dams and seven check dams for improving the groundwater potential in the district were also included in the DPR.

Hydrogeological and geophysical investigations has been carried out for pin pointing borewell drilling sites. The sites were identified by involving people's representatives and then approved by the District Collector. The hydrogeological investigation for source finding to pre-point drilling sites is done by the Central Ground Water Board (CGWD). The drilling of borewells has been done by the rigs of Kerala Water Authority and State Ground Water Department. Private rigs were also engaged on contract basis.

CGWD has been the Nodal Agency for detecting groundwater sources. The successful rate was as high as 88% during drilling operations of borewells utilizing data provided by the CGWD. Natural springs on mountain ranges have been successfully tapped for the use of people living on mountain slopes. Three schemes of such type were commissioned in the district. They are executed through Block Panchayaths.

Under this Mission, almost all villages in Palakkad have been covered with a total of about 1200 borewells with handpumps. Twenty three good yielding borewells were energised and linked to the existing piped water supply network of KWA. Two check dams and three sub surface dams have completed so far and the construction for others is under progress (KWA, 1993).

The introduction of handpumps in Panchayaths saved a substantial amount of money for the Revenue Department on supplying lorry water during summer in drought hit areas. The handpumps installed under Mini-Mission have been handed over to the Panchayaths for attending operation and maintenance. To make the Panchayath self sufficient in the maintenance of handpumps, training to mechanics in each Panchayath is being conducted. The required tool kits, received from UNICEF as a gift, have been handed over to the Panchayaths. There are no separate ear marking of funds for operation and maintenance of assets created.

Apart from the above activities, the Mission had also arranged training in handpump operation and maintenance. The Mission took active role in integrating different Government departments such as Health Dept., Education Dept. *etc.* for fluorosis awareness programmes. It also arranged community participation with the active involvement of NGOs. Mission also performed monitoring and evaluation activities of water supply projects to a certain extent.

There are no reported cases of guineaworm problems in Palakkad. During the Mission activity period, either any Desalination plants, or any Iron removal plants or any Defluoridation plants were installed. The Mission activities have been stopped in 1995. The Divisional Office, KWA, Palakkad has been entrusted to complete the arranged balance works.

(2) Activities under Kerala Water Authority

Following National Policy, many handpump schemes were constructed in the State of Kerala. Palakkad District was also covered in this programmes. In 1983, a severe drought affected the district and in order to supply water to the rural people, the government agencies, especially the then State PHED started a massive drilling programme. Funds were provided through the State Budget, under the head of Drought Relief Works (DRW). It was found that this handpump systems are very effective in covering the isolated hamlets and villages within a short time. Moreover the topography and soil profile favored this option. Normally the drilling of boreholes can be completed within one day and if the materials are available, the scheme can be commissioned within few days. Because of this short time requirement, borewells with handpumps became a popular method for providing drinking water in that season.

Following the success of drought works, State government started financing the rural water supply programmes in Palakkad through programmes like Minimum Needs Programme (MNP), Accelerated Rural Programme (ARP), Special Component Plan (SCP) and Tribal Sub Plan (TSP). A part from these programmes, funds were allocated in each year to overcome the drought season of the district. A portion of the money was earmarked for the construction of handpumps. The handpumps are then handed over to the Panchayaths for operation and maintenance.

Out of the 155 villages, almost all are partially covered with water supply. There are about 131 piped drinking water supply schemes and 2200 borewell with handpumps (including drilled under RGNDWM). The details of borewells fitted with handpumps and power pumps are in table 2.1.

Table 2.1: Details of borewells as on 1996.

Sl.No.	Name of Block Panchayath	With Handpumps			With Power pumps		
		KWA	TM	Total	KWA	TM	Total
1	Alathur	91	119	210	18	2	20
2	Coyal Mannam	85	150	235	7	2	9
3	Chittur	117	126	243	11	3	14
4	Kollengode	79	144	223	11	3	14
5	Palakkad	43	41	84	5	1	6
6	Malampuzha	65	79	144	8	4	12
7	Mannarkkad	73	72	145	4	0	4
8	Attappadi	65	40	105	0	0	0
9	Sreekrishnapuram	81	89	170	4	0	4
10	Pattambi	92	121	213	15	1	16
11	Ottappalam	95	76	171	11	2	13
12	Trithala	101	127	228	5	0	5
	Total	987	1184	2171	109	23	132

KWA - Drilled under Kerala Water Authority
TM - Drilled under Technology Mission i e the Mini-Mission under RGNDWM
(source KWA, 1996)

Chapter 3

Literature review

This chapter covers the literature on handpump water supply, functioning of handpumps and its use in general. The chapter mainly consists of three sections. The section begins with the history of handpumps and the development of India Mark II handpumps and its recent modifications. Then it describes the functioning of handpump systems in general including the various factors affecting the functioning. It ends with the use of handpumps which also explains the various parameters involved and its relationship with the use of handpumps.

3.1. Handpump Water Supply

The provision of safe, reliable and convenient water resources is generally recognized as an essential service, and considered a precondition for achieving a minimum standard of living, good health and economic progress. Handpumps installed in the wells, where groundwater of appropriate quality is readily available, provide one of the simplest, safe and least costly methods of supplying drinking water to rural and urban fringe areas. Because of budget limitations, it is apparent that only such low cost options can lead to wide coverage of improved water supplies(Ghosh et al, 1995).

3.1.1. History of handpumps

The history of handpumps goes back a long way. Literature says the positive displacement reciprocating pumps were in use as early as 275 B.C. in Ancient Rome. One of the best documented early examples of a wooden pump of lifting type, using metal flap valves was recorded by Agricola in the sixteenth Century. The use of reciprocating pumps made of wood or lead were common in England during the seventeenth Century (McJunkin, 1977).

Most of the reciprocating handpumps in developing countries today have their origin in designs developed during the late nineteenth and late twentieth Centuries in Europe and United States. The Industrial Revolution brought mass production techniques and it has been estimated that, by the end of the second decade of the twentieth Century, about three thousands manufacturers produced more than 40 million handpumps in the U.S. alone (Arlosoroff et al, 1987).

The basic design of the reciprocating handpump has not changed much in the twentieth Century, but its use has. In normal cases, the most popular European backyard pump, was only used by an individual family or a farm for about 10 to 30 minutes a day. But when this pump has been introduced in the developing countries, it has to meet the demands of a large number of people with a continuous operation of 10 or more hours a day. The extensive use of these pumps have resulted in frequent breakdowns in handpump water supplies. Also different pump types such as the diaphragm type and the progressive cavity pumps were also in use in developing countries.

The non-uniformity of pump types, associated with its spare part problems resulted frequent breakdowns in handpump water supply systems. It was at this time, the UNICEF came up with the sponsorship programme on handpump research and development, with a view to improve the designs of handpumps to suit the local conditions, particularly in the developing countries (Arlosoroff et al, 1987).

3.1.2. Handpump Developments in India

Borewells fitted with handpumps have become one of the major sources of water in the rural areas of India. Borewells are the ground water extraction structures which can be used to tap the water available in the fractured rock aquifers. These borewells drilled with DTH rigs[1] have a blind casing up to the hard rock to take care of the caving in of the overburden and a naked hole in the hard rock into which water enters through the fractured horizons.

Reciprocating handpumps, for drawing water from below ground, have been in use for centuries. During the early 1960s, reciprocating type handpump designs meant for small user groups were introduced in India to pump water from deeper borewells with substantially large user groups. Some of the handpump which were in use are;

① Dempster pump
② Double guide pump
③ Double guide with conversion head
④ Vadala pump
⑤ Sholapur pump, and
⑥ Jalna pump

(source : UNICEF)

These pumps failed too frequently and were unable to provide a constant source of drinking water. Then in the early 1970s Government of India(GOI) initiated action in cooperation with the state governments, World Health Organization(WHO), United Nations Children's Fund(UNICEF), Mechanical Engineering Research and Development Corporation(MERADO) and Richardson & Cruddas (1972) Ltd.(a GOI undertaking), for the development of a dependable deepwell handpump. This resulted in the development of the reliable and sturdy India Mark II handpump in the late seventies. The first Indian National Standard for India Mark II pump appeared in 1979, with number IS 9301, Indian Standard Deepwell handpumps Specifications. Later this has been revised thrice with the latest in 1990 (source: UP Jal Nigam, 1995).

The four major assemblies of India Mark II handpump are;

① *Pump head assembly (above ground mechanism)*:
Fully hot galvanized fabricated steel structure consisting of head assembly, water tank

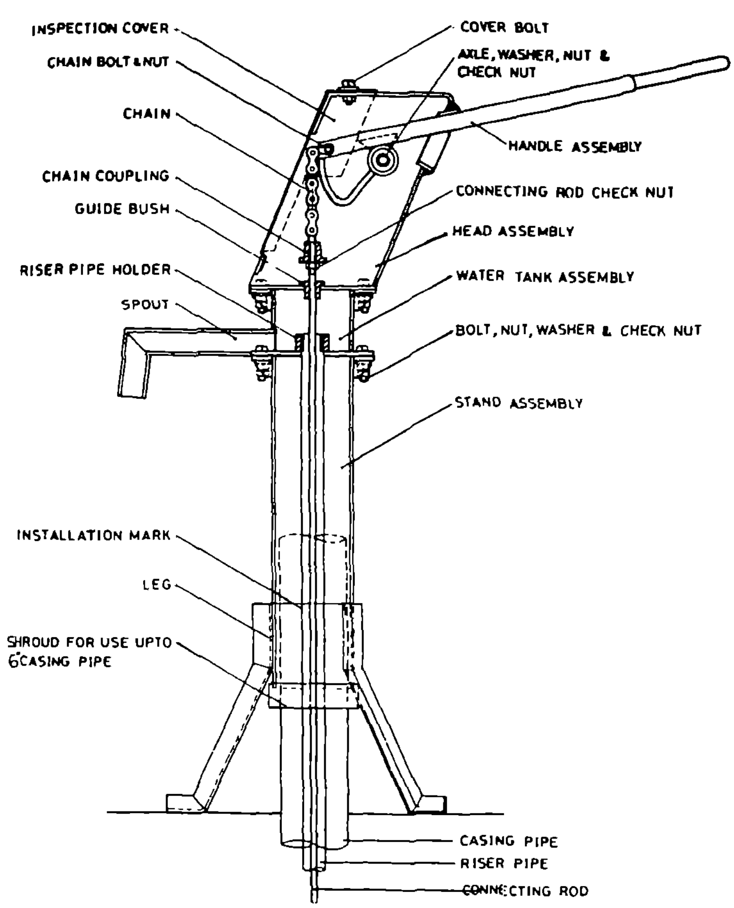
[1] DTH rigs - Down The Hole rigs · the principle of the down the hole drilling is that the rotary unit is positioned on a feed above ground, while the impact mechanism is located just behind the drill bit

and stand assembly(pedestal). The figure 3.1 gives the details of a pumphead assembly of India Mark II Handpump.

② *Cylinder assembly*:
Cast iron body fitted on the inside with a seamless brass liner having excellent inner surface finish. Plunger and foot valve are of gun metal as per IS 318-1981 with nitrile rubber buckets and sealing rings.

③ *Connecting rods*:
12 millimetre diameter electro-galvanized mild steel bright bars of length 3.0 metres along with hexagonal couplings and locking nuts.

④ *Riser pipe*:
32 millimetre nominal bore galvanized iron medium class pipe in 3.0 metre standard length along with coupling sockets. (source: UP Jal Nigam, 1995).



SECTIONAL DETAILS
OF PUMPHEAD ASSEMBLY
figure 3.1

India Mark II deepwell handpumps benefit an estimated 360 million people in Asian, African and Latin American countries. In a decade, the India Mark II handpump became a household name in villages in India. India, with the largest national rural water supply program in the world, has over 1.3 million Mark II deepwell handpumps installed in rural and peri urban areas to provide safe water to over 260 million people (Dept. of Rural Development., GOI, 1990).

The development of the India Mark II was a major breakthrough in terms of reliability and ease of operation. The number of handpumps operating at any point of time rose from a dismal 25% to an impressive 85%. However, this pump relies heavily on centralized maintenance. A mobile team consisting of a van with special tools and 4 or 5 semi-skilled workers is needed to provide specialized maintenance. This system is expensive and difficult to sustain. Alternative models of decentralized maintenance have been tried out with limited success (Dept. of Rural Development., GOI, 1990).

It was necessary to introduce changes in the existing India Mark II handpump for encouraging the maintenance of handpumps by the users themselves. The "Village level Operation and Maintenance"(VLOM) concept has been promoted by various agencies, including UNICEF and the UNDP/World Bank Water and Sanitation Program since the early 1980s. The VLOM concept promotes the maintenance of a handpump by the users themselves with minimal outside support. It demonstrates that it is possible for pumps to be maintained by users themselves with minimum downtime and lowest financial and economic cost, provided it is technically easy and spare parts are made available (Dept. of Rural Development., GOI, 1990).

In this context, in India a project was started with an aim to improve the reliability and serviceability of the widely-used India Mark II handpumps(Coimbatore handpump project). Approximately 80 handpumps were tested over a period of four and a half years under conditions of heavy use and deep static water level. A sample of 50 standard India Mark II handpumps provided the baseline information with which the performance of the experimental variations were compared.

Initially all test pumps were fitted with the standard India Mark II pump head and leather cup seals. However, as the field testing and monitoring progressed, refinements were carried out in the standard India Mark II handpump as well as the experimental handpumps.

They are;

(a) India Mark II : In this pump the above ground mechanism was modified slightly to facilitate easier and quicker removal for access to the below ground parts. The changes include a nitrile cup seal instead of a leather cup seal and a two piece upper valve instead of a three-piece upper valve and a modified spacer.

(b) India Mark III : This pump uses a 65 mm internal dia. G.I. pipe for the rising main to facilitate withdrawal of the extractable piston and foot valve without having to remove the rising main. The pump's above ground mechanism was modified slightly to facilitate its easier and quicker removal for access to the below ground parts.

Analysis of field data shows the following distinct improvements in the reliability and serviceability of the experimental pumps - India Mark II (modified) and India Mark III deepwell handpumps over the standard version India Mark II deepwell handpumps. In the India Mark III deepwell handpump, the average frequency of service required (from a mobile maintenance team) was reduced by 67%. In fact, 90% of the total repairs for the India Mark III deepwell handpump can be carried out by a bicycle-mobile mechanic using few tools and with the assistance of the handpump caretaker/users(Dept. of Rural Development., GOI, 1990).

Recommendations of the Coimbatore Project are;

① Design improvements to the India Mark II deepwell handpump be incorporated into the national standard specifications.

② The existing 1.3 million India Mark II deepwell handpumps be modified to substantially increase the MTBF[2].

③ The India Mark III deepwell handpump be installed on a large scale in all the states presently using the India Mark II deepwell handpumps and a village-based maintenance system be developed which needs minimal support from a mobile team.

④ A national standard be prepared for the India Mark III deepwell handpump.

⑤ A study on a national level be conducted to evaluate the strengths and weaknesses of the various existing maintenance systems and to suggest ways to create village level capacity to repair deepwell handpumps.

⑥ Further research and development should be undertaken to simplify maintenance requirements which will encourage the users themselves to carry out maintenance. (source : Dept. of Rural Development., GOI, 1990).

The Bureau of Indian Standards has adopted the VLOM design of India Mark II handpump, named as India Mark III type. A National Standard Code, Indian Standard Deepwell handpumps (VLOM) Specifications IS 13056 : 1991 has prepared. The following figure 3.2 gives the details of an India Mark III deepwell handpump.

[2] MTBF - mean time before failure, defined as the duration for which the handpump operates satisfactorily.

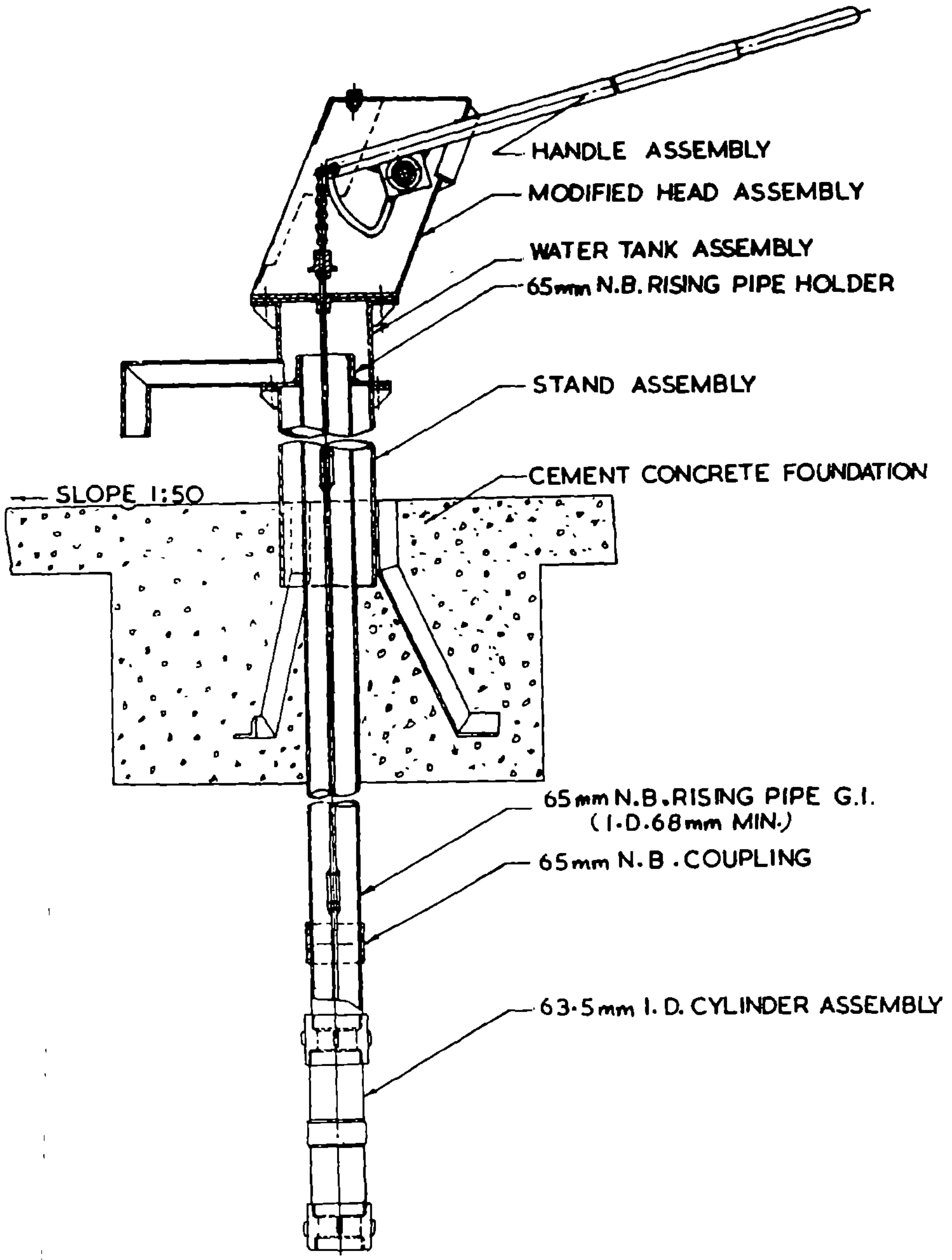


figure 3.2 India Mark III Deepwell Handpump

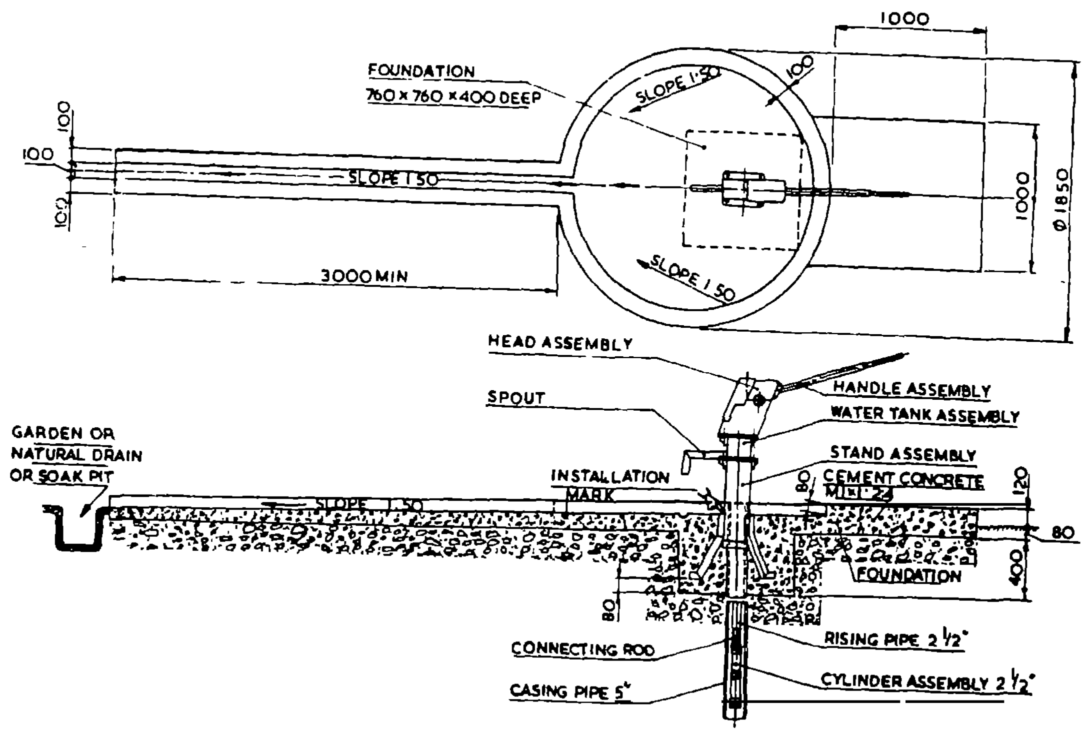


figure 3.3 Installation details of an India Mark III Deepwell handpump

3.2. Functioning of Handpumps

It was already considered at the United Nations Conference in Mar del Plata, 1977 , that 'all peoples, whatever their stage of development and their social and economic conditions, have the right to access to drinking water in QUANTITIES and of a QUALITY equal to their basic needs'.

In pursuing the fulfilment of this right, quantitative and qualitative aspects of supplying safe and adequate drinking water have to be equally taken into consideration:

(a) *safe water* ,*i.e.* water free from chemical substances and micro-organisms in concentrations which would cause illness in any form; and

(b) *adequate water supplies, i.e.* providing safe water in quantities sufficient for drinking, culinary, domestic and other household purposes including the personal hygiene of members of the household. It should also provide sufficient quantities on a reliable, year-round basis near to the household where the water is to be used(source : Lloyd and Helmer, 1994).

A normally functioning handpump should be able to supply adequate quantity of safe water for the domestic needs of the community.

In the past, there have been serious problems with the poor performance and short working life of most handpumps used for community water supply. Some of these problems are associated with handpump design, selection and quality of manufacture. Others are rooted either in the behavior of handpump users or in the organization of handpump installation and maintenance programme. Review of a number of handpump projects indicates that handpump failure may be attributed to one or more of the following:

① Lack of institutional infrastructure, proper maintenance, spare parts, trained personnel and appropriate budgets.

② Pumps which are not designed for continuous use by entire communities nor for repair and maintenance by villagers.

③ Improper borehole design and construction.

(Source : Arlosoroff et al, 1984)

The parameters which may have an effect on the normal functioning of handpump systems are;

① Pump discharge,
② Leakage,
③ Breakdown frequency,
④ Average downtime,
⑤ broken and badly constructed platform,
⑥ water quality, and
⑦ maintenance system.

3.2.1. Pump discharge

Commonly used handpumps in India are India Mark II pumps. They are single acting[3] reciprocating pumps. The theoretical rate of discharge of a single acting reciprocating pump is a function of the cylinder volume (V) swept by the plunger during its upward, pumping stroke and the number of plunger pumping strokes per unit time (N). That is discharge, Q = V * N. The volume 'V' is the product of the horizontal cross sectional area(A) and the length of the plunger stroke(S). The discharge from reciprocating pump is directly proportional to N or to S.

[3] single acting - discharge only in one direction, normally during the upward movement of the plunger.

The actual discharge normally varies slightly from the theoretical discharge due to failure of valves to close instantly when the plunger changes direction and to back leakage between the plunger and the cylinder wall during pumping. This difference is known as slip. In a well designed and maintained pump, the slip should not exceed 15 percent, preferably 5 percent. Under certain conditions, the actual discharge may exceed the theoretical discharge(in terms of swept cylinder volume) and hence negative slip is possible. This can happen in case of a long suction pipe of small diameter below the cylinder which may result in a sufficiently high flow velocity to keep open the plunger discharge valve during part of its upward movement (McJunkin, 1977).

The Indian Standard Code for Deepwell handpumps IS 9301 describes a 'type test' to be conducted in the field for assessing the pump performance. It says "The performance of the pump shall be checked after placing the cylinder at 50 metre below the ground level in a borewell, the yield of which shall not be less than 20 litres per minute. The pump shall be primed and tested only after getting continuous flow of water through the spout. The water shall then be collected in a container for forty continuous strokes to be completed in one minute and the discharge thus measured shall not be less than 12.0 litres".

The results of the field tests conducted in more than 200 India Mark II handpumps in Ghana are also presented in table 1. The average depth of selected borewells is 40 metres, which varied from 25 to 80 metres. The static water level varied from 0 to 42 meters with an average of 11.5 metres.

Table3.1: Discharge rate for India Mark II handpumps

	Cylinder dia.in inches	30 strokes/minute			50 strokes/minute			70 strokes/minute		
		min	max	ave	min	max	ave	min	max	ave
Discharge in lit. per minute	2.5	6.9	11.7	9.5	10.1	25.0	16.6	17.8	33.0	23.9
	2.0	5.3	6.8	6.1	7.3	13.5	10.2	13.7	16.7	14.8

(source : Arlosoroff et al, 1984)

The measurement of pump yield is essential to compare the performance of different pump components. Lower discharge of the pump may result in more strokes for collecting a bucket of water, subsequently more wear and tear of the pump material resulting in a poor functioning of the system.

3.2.2. Leakage

A handpump is said to have leakage when no water is discharged from the pump within the first three strokes after approximately 5 minutes without pumping (Arlosoroff, S. et al., 1984). Obviously leakage in a pump will increase the number of strokes required for the collection of a bucket of water and hence more physical strain and time consumption. Leakage may lead to more wear and tear of the pump materials, which can result in frequent repairs and poor performance of the system.

Field tests conducted in Ghana reports "Leakage, mainly caused by loosened or defective couplings, in the rising main was a major poor performance for the India Mark II pumps and particularly at the beginning of the monitoring. This appears to be due to poor installation" (Arlosoroff et al, 1984).

3.2.3. Breakdown frequency

Breakdown frequency is the number of times the system breaks down within a specified period of time. It can be expressed such as once in a month or once in two months or so. The reliability of a pump can be measured by the number of occasions a pump breaks down or needs major repairs to keep it in working condition.

In the test project at Coimbatore in India, a centralized maintenance system was adopted. The reliability is measured by the number of visits required by the mobile maintenance team. Based on four years experience, it was estimated that on an average the major repairs that need a mobile team's attendance will perhaps be once in 6 years. The overall frequency of replacement of parts is 9.15 per pump per year for India Mark II. The frequency of rising main replacement was the highest which stood at 2.36 parts replaced/ pump/ year (Dept. of Rural Development., GOI, 1990)..

The quality of materials and job execution are important for lowering breakdowns and thus good performance. Poor performance are often due to problems related to the material from which the components are made, fabrication of components, pump installation and well construction (Arlosoroff et al, 1984).

The problems related to material defects are;

(i) breaking of rods, couplings, etc.,
(ii) leakages due to defective couplings and corrosion, and
(iii) hard pumping and rod breakage due to inaccurate tolerances.

Many problems are related to lack of adequate care in the installation of handpumps. They are,

(i) disconnected pump rods, rising mains, etc. due to improper tightening of couplings, nuts and bolts.

(ii) hard pumping and or extreme wear due to maladjustments or bad alignments of parts of the pumps, and

(iii) entering of dirt and polluted water into the well if pump stands are not sealed off, etc.

The following problems have been encountered due to poor well construction methods in the field and have an adverse impact on durability; they are,

(i) sand, silt and clay in the water(up to one volume percent of sandy-silty material has been measured in ground water from boreholes equipped with handpumps),

(ii) pump cylinders that are not immersed, or only partly immersed in water(probable causes for this are clogging of screens and gravel packs, insufficient well development, depletion of aquifers and water quality).

(source : Arlosoroff et al, 1984)

3.2.4. Downtime

Downtime is defined as the period of time when the pump is not available for normal use. It consists of :

(i) The time taken to report a breakdown;

(ii) The time lag between the receipt of breakdown report and actually reaching the pump to commence repair ; and

(iii) Active repair time i.e. the time actually taken to carry out repairs.

It is estimated that 85% of the India Mark II handpumps remain operational at any point of time. This would mean that the India Mark II handpump remains idle for approximately 50 days in a year. The ORG[4] report notes that reporting breakdown varied from 4 to 13 days while the time taken to put the pump back in operation varied from 7 to 44 days after the receipt of the report. This report points out that, on an average, a Mark II pump remains inoperative for 37 days per year. This not only causes hardship to the community, but also keep the investment idle (Dept. of Rural Development., GOI, 1990).

The higher the downtime, the lesser will be the functioning of the system.

Cost effect of downtime for India Mark II handpumps

The following tables give the justification for the maintenance cost arrived for the centralized maintenance system adopted in the Coimbatore Project which consisted of 5 persons and a mobile van. The following assumptions are made for arriving at the maintenance costs.

(i) one care taker for each handpump;
(ii) one block mechanic can repair 1500 handpumps in one year;
(iii) one mobile team with a van can repair 300 handpumps a year;
(iv) cost of spare parts have been calculated based on the frequency of replacement of each

[4] ORG - Operation Research Group

spare parts.
(source : Dept. of Rural Development., GOI, 1990)

Table 3.2 : Maintenance cost of centralized maintenance per pump per year for India Mark II handpump

Item	Rupees
(a) Caretaker	40.00
(b) Block mechanic	18.61
(c) Mobile team	392.10
(d) Spare parts	423.50
Total	874.21

(source : Dept. of Rural Development., GOI, 1990).

Table 3.3: Cost of Downtime in India Mark II handpump per year

Item	Rupees
1. Capital Cost	24,950.00
2. Maintenance Cost from table 2.	874.21
3. Interest @ 12% annum on total cost	2994.00
4. Depreciation (15 years approximately)	1663.33
5. Total of (2+3+4)	5531.54

(source : Dept. of Rural Development., GOI, 1990).

Hence the cost of operation per day is Rs[5]. 15.16. When an India Mark II pump does not work, the loss is approximately Rs.15(US$1.5) per day. If a pump is inoperative for 37 days in one year, the loss of benefits to the community in indirect financial terms(since the service was provided by the government) will be Rs.560.92(US$54) per year. Apart from this the loss of time involved in drawing water from a more distant source and the potential adverse impact on the health of the community is also significant (Dept. of Rural Development., GOI, 1990).

The high downtime of the Mark II in the field is possibly due to the following factors.

(i) delay in reporting breakdown;

(ii) communication delays;

[5] Rs - Indian Rupees (1985 exchange rate)

(iii) delay in taking action on receipt of breakdown report; and

(iv) use of non-standard spares and faulty installations.
(source : Dept. of Rural Development., GOI, 1990)

3.2.5. Broken and badly constructed platform

The heavy use, improper construction and/or bad quality of materials can result in broken platforms. This may ultimately affect the stand assembly and loosening of which may develop more wear and tear of the pump materials. Wear and tear of pump parts may lead to regular breakdowns which may affect the functioning of handpumps very badly.

3.2.6. Water quality

The water quality of the ground water may also play an important role in the functioning of handpumps.

The corrosive property of ground water can affect the handpump performance badly. It affects the mechanical performance, leading to broken pump rods and damaged pipes. Although these mechanical failures usually originate from a combination of causes (e.g. rubbing of rods on rising mains, fatigue of material, poor handling of the equipment etc.), a high percentage of handpump failures are attributable to corrosion. In southern Ghana, it was found that up to two thirds of the handpump defects(rod breakage) were directly related to corrosion (Langenegger, 1994).

Corrosion is the attack of the surface of materials by chemical processes. The pH of handpump water is influenced by corrosion. The pH of groundwater from a well equipped with a non-corrosion resistant handpump can decrease by as much as half a pH unit after replacement with a corrosion resistant pump (Langenegger, 1994).

The threads of both pump rods and rising mains are weak points that are particularly vulnerable to corrosion for the two reasons:

(1) because any protective coating applied to rods and pipes is removed when the threads are cut or easily damaged during pump installation and maintenance; and

(2) thread cutting removes the material, thus reducing the wall thickness of pipes and the diameter of the rods.

Corrosion can cause pipe perforation and damages to threads, resulting leakages in the rising main. This may result reduced discharge rate and hence poor performance of pumps. Field study conducted in Western Africa indicated a high corrosion rate in mild steel in the low pH range(pH < 6.5), with a gradual decrease at high pH levels (up to a pH of about 8). In contrast to mild steel, zinc showed a rather constant corrosion rate levels at low pH levels(pH < 7) and a relatively rapid decrease in corrosion rate at pH in the proximity of 7. At pH < 7 the corrosion rate of mild steel was about two to four times higher than that of zinc. With regard to application of galvanized components for handpumps, the result indicates that protection against galvanization is only effective when the pH > 7. Below this range the corrosion of zinc is rather constant which explains the rapid removal of zinc coatings on rising mains observed in the field (Langenegger, 1994).

3.2.7. Maintenance system

Maintenance is an inevitable requirement of any system which depends on mechanical equipment. In most handpump projects, a centralized mobile maintenance team run by national or regional government or a donor organization is responsible for maintenance for large numbers of widely dispersed handpumps. The central organizations, with few spares of the pumps and vehicles, few operational vehicles and long response time are often unable to provide this service satisfactorily. Their budgets are too low, management is inadequate, and there are few incentives for staff to perform well. In few cases where centralized maintenance is effective, usually with donor support, it is expensive (Arlosoroff et al, 1987).

In recent years, backed by strong promotion from the project, the governments in the developing countries governments have recognized the short comings of centralized maintenance and the need for greater community involvement. This has resulted in the development of the so called VLOM concept, the Village Level Operation and Maintenance. Possible handpump maintenance system cover a wide spectrum, from total community management with no external intervention to complete control by the government water agency or other external organization with no involvement of community at all (Arlosoroff et al, 1987).

(i) Community Management of Maintenance

The key element in this type of management is community choice. The water committee or other community organization finances and organizes all handpump maintenance repair. Success is related to a sense of community ownership of the well and pump can only be achieved when the organizational capacity of the community is adequate. For community management to be feasible, the selected pumps must be suitable for simple routine maintenance with basic tools and minimal skills. Common spare parts must be readily available in or near the community, which will usually mean that they are manufactured locally : and there must be suitable community structure for recovering the costs of maintenance and repair operations (Arlosoroff et al, 1987).

(ii) Central Management of Maintenance

A governmental or other agency maintains the handpumps, with mobile teams traveling from base camps to carry out repairs. There are two types of such maintenance, depending on whether the community participates in maintenance activities. There are two types;

(a) Central maintenance with community involvement :

Responsibility for carrying out and financing operation and maintenance is divided between the community and an external agency - usually the government water authority, but sometimes a parastatal organization. This division of responsibilities is specifies in agreement settled in discussions with community leaders in the planning face of the project. Pump maintenance is managed by the external agency, with the community accepting certain responsibilities as part of its contribution to the scheme.

(b) Central maintenance :
This remains the most common form of handpump maintenance and will continue to be needed for the more complex and heavy handpump types and for deep pump settings. The usual form consisting of a public sector organization managing mobile maintenance teams strategically located across the region. The teams report to a national or regional headquarters which handles overall budgets and spare part procurement and distribution. Each team includes skilled workers equipped with special tools and motor vehicle . Handpumps are visited when the community reports a breakdown or, in exceptional cases, according to a regular maintenance schedule (source : Arlosoroff et al, 1987).

The three maintenance strategies prevailing today are (i) *breakdown repairs,* (ii) *limited preventive maintenance* and (iii) *routine inspections and preventive maintenance.* A strategy based solely on response to breakdowns or serious drop in performance may lead to unnecessary damage to other parts of the equipment, and hence more expenses at the end. The limited preventive maintenance in which community members lubricate moving parts and tighten loose bolts can have a significant impact, bu reducing the number of breakdowns and spotting the need for repair in good time and good functioning of the system (Arlosoroff et al, 1987).

3.3. Use of Handpumps

Water use may be defined as the volume of water used for different purposes. The domestic use of water includes the water required for drinking, cooking, washing, personal hygiene, vegetable garden watering, and cattle feeding. The factors influencing the water use includes cultural habits, pattern and standard of living, whether the water is charged for, and the cost and quality of the water.

The study conducted by UNICEF through IMRB[6], a premier market research organization of India revealed some behavior patterns, knowledge, belief and practice in terms of water use and hygiene practices in different parts of the country. Popular definition of safe drinking water is water that is visually clear, tastes sweet, free from unpleasant flavors and odours and cooks food well and quickly. While look and taste are universally used evaluation criteria for water, its cooking quality is particularly important for women, who make the final choice about the water source used for drinking/cooking in their families. Most implementors are conscious of the significance women attach to the cooking quality of water (UNICEF, 1989).

The same study revealed that about 93 per cent of the people interviewed defined good and safe water as one that visually appears clear and 87 percent are of the opinion that water that is sweet to taste is safe while only 12 percent indicated that water free from germs is safe for drinking

[6] IMRB - Indian Market Research Bureau

purpose. Sixty eight percent of the people defined bad water as one which does not cook well. There is large area of public ignorance about how health is affected by unsafe drinking water. Across the states 88 to 95 percent people believe that bad drinking water causes health problems. Only 10-18 percent people interviewed across the country are aware that bad drinking water causes diarrhoea, stomach disorders, cholera etc (UNICEF, 1989).

As long as the users consider the costs(economic or other) of using the new supply higher than those of using the traditional sources, they will continue to use the traditional ones, even if they are further away(Carr and Sandhu, 1988). This is related to how people value the various resources involved, including their own labour. The more is the cost of new water supply system, the lesser may be the acceptability.

The water use from a handpump may depends on

① number of persons using the handpump;
② volume of water collected per day per capita;
③ distance of handpump from the household;
④ presence of alternative water sources;
⑤ water quality;
⑥ pump environment;
⑦ condition of pump; and
⑧ community involvement.

3.3.1. Number of persons using the handpump

This number indicates the level of service as it indicates how accessible the water supply is. The water use from a handpump depends on the service level provided by the system. The service level for a handpump relates to the number of people served from each pump and the walking distance to the pump (Arlosoroff et al, 1987). Part of the community's evaluation of the costs and benefits of different service levels will be the value of time spent queuing and hauling water.

Also, the factors affecting the functioning of handpumps may indirectly affect water use. The other factors affecting acceptance include the waiting time, presence of alternative water sources and its distance from households.

The waiting time, i.e. the time spent on waiting near the handpump may depend on the yield of well, discharge of the pump, and leakage. Waiting time may be different for different hours of the day. It is higher during the peak hours of demand, especially in the morning and evening hours of the day. Poor discharge and/or leakage may increase the waiting time which may affect user acceptance very badly.

The daily output from a handpump is controlled by several factors, the most significant being the pumping lift. There are thus practical limits to the number of people who can obtain water from one pump, which vary with the depth of the water table (Arlosoroff et al, 1987).

The more the people served, the longer will be the queues and greater the risk that people will return to alternative traditional sources. Pump breakdown frequencies are also directly related to hours of pumping, so that greater intensity of pump use will mean more frequent needs for maintenance or repair. The improved accessibility of a new water source may improve the situation.

3.3.2. Volume of water collected per household

Depending on climate and workload, the human body needs about 3 to 10 litres of water per day for normal functioning. Part of this water is obtained from food. The use of water for food preparation and cooking is relatively constant. The amount of water used for other purposes varies widely, and is greatly influenced by the type and availability of the water supply (Hofkes, 1986).

Water consumption rate is frequently expressed in litres per capita per day (lpcd). Although such data neglects the fact that in a household a considerable part of water use is shared by all members of a family (e.g. for cooking, cleaning), per capita daily water usage data are useful for making rough estimates of a community's water demand (Hofkes, 1986).

The table below gives typical domestic water usage for different types of water supply systems.

Table 3.4: Typical water consumption rate and its range

Type of water supply	Typical water consumption lpcd	Range lpcd
Communal water point (e.g.. Village Well, Public Standpost)		
- at considerable distance (> 1000 m)	7	5 - 10
- at medium distance (500 - 1000 m)	12	10 - 15
Village Well		
walking distance < 250 m	20	15 - 25
Communal Standpipe		
walking distance < 250 m	30	20 - 50

(source : Small Community Water Supplies, Technical Paper No. 18, IRC)

Normally the supply level provided by the handpump scheme comes in between that of village well and communal standpipe.

The factors which may have affect the volume of water collected are;

(1) *waiting time:*
Long waiting time may reduce the acceptance of a system by the people.

(2) *discharge:*
Either due to the improper construction or due to damages in rising mains, leakages etc., the discharge from a handpump may reduce. The lower the discharge, the longer may be the queue to collect water and then lesser may be the user acceptability.

3.3.3. Distance of handpump from the household

The distance between the households and the handpump may be an important indicator for the community acceptance. Table 4. suggests that the consumption rate is the lowest when the distance to the water source is more. Also long distance to the source may result in more consumption of time and more physical strain in hauling water. This makes the new source less attractive. UNICEF has identified the distance to the borewell as the single largest cause for general non-use of handpump schemes (UNICEF, 1989).

3.3.4. Presence of alternative water sources

The presence of alternative water sources may have an impact on the user acceptability. Demand for water from handpumps may be low if alternative sources are easily available. The demand of water for uses other than household uses, such as livestock watering and gardening were also have to be met by the new water source. If these demands cannot be met, people may start to depend the nearby available traditional sources again.

3.3.5. Water quality

Water quality examination is basically a determination of the organisms, and the mineral and the organic compounds contained in water. The physico-chemical composition of groundwater plays an important role in the study of groundwater quality, particularly its effect on user acceptance, its effect on technical aspects of water use, and its effect on industrial and agricultural applications.

The basic requirements of drinking water are that it should be

- free from pathogenic(disease causing) organisms
- containing no compounds that have an adverse effect acute or in the long term, on human health
- fairly clear (i.e. low turbidity, little colour)
- not saline(salty)
- containing compounds that cause an offensive taste or smell
- not causing corrosion or encrustation of the water supply system, nor staining clothes washed in it.

(source : Lloyd and Helmer, 1994)

The parameters which may affect the water use from handpumps are;

(1) Taste

Taste may be an important reason for rejection of handpump systems. The majority of consumer complaints about water quality all over the world are related to taste and/or odour problems caused by the turbid or discoloured water and deposits (Mallevialle and Suffet, 1987). Excess iron can also give taste to water. Human beings are very sensitive to taste, odour and aesthetic parameters of water quality. Literature says that the combined effect of distance and poor taste of borewell water forces the people to use these schemes for purposes other than drinking(UNICEF, 1989). Difference in taste of the new water source may reduce the acceptability.

(2) Color

Color in water is mainly due to the presence of organic compounds derived from soil humus which, in turn, is produced from the decay of plant or animal matter. The presence of natural metallic ions such as iron and manganese are the main reasons for colour in ground water.

Color may affect the user acceptability badly. High coloured water is objectionable because it may stain household fixtures and clothing. It may also reduce the aesthetic appeal.

(3) Electrical Conductivity (EC)

Electrical conductivity is a measure of the ability of water to conduct an electric current, and this is an indication of the total amount of dissolved ions in water. The electrical conductivity is very useful in determining water quality.

As EC is an indicator of the ions dissolved in water, which are about proportional to the amount of dissolved matter, the EC can also be used to estimate the total filterable residue or total dissolved solids (TDS). The TDS is obtained by multiplying the EC by an empirical factor, which ranges from 0.55 to 0.9 and depends upon the soluble components and the temperature. For drinking water a mean value of 0.7 is suggested. The EC increases with temperature.

The EC is not a good indicator of water quality with regard to health hazards. It is however, an indicator of salinity which is an important factor in taste and thus user acceptance of water points. WHO does not directly consider the EC in guidelines for drinking water quality (WHO, 1984), but it does give recommendations for TDS because of taste considerations. As per ISI, water with TDS < 500 mg/l (app. EC 700 μS/cm) is suitable for drinking. Beyond this the palatability decreases and may cause gastro intestinal irritation. The major constituents contributing to EC are the hardness components of Calcium (Ca^{++}) and Magnesium (Mg^{++}). Nitrate, sulphate and chloride may also make significant contributions to the EC.

(4) Turbidity

It is caused by suspended materials such as mineral particles (silt, clay, corrosion products), soluble organic compounds, micro organisms (plankton etc.) And other microscopic organisms and particles. Turbidity thus is a measure of water clarity and is an indicator for its optical properties.

Turbidity does not have a direct impact on health. But high turbid water is less acceptable to consumers from aesthetic view point. Also it is more difficult to achieve effective bacterial disinfection using chlorine when the concentration of the suspended solids is high. It appears that the solids provide the attached bacteria a protective barrier against the action of the chlorine added for disinfection.

According to WHO, the threshold at which turbidity can be detected by the naked eye is above 5 NTU.

Ground water pumped from handpump equipped wells can have higher turbidity and, thus lower water quality, than the original ground water because of the presence of suspended corrosion products, mud entering wells because of defective aprons or improperly installed pumps(poorly sealed base plates) (Langenegger, O., 1994).

(5) Iron

Iron occurs in the water in the ferrous and ferric forms. The guideline values for total iron concentration in drinking water should be less than 0.3 mg/l(ISI, 1991). This value is based on aesthetic considerations, beyond this value, taste/appearance are affected and has an adverse effect on domestic users and also promotes growth of iron bacteria. High iron concentration in water can stain the platform in case of handpump schemes. It will also stain clothes when washed. Hence high iron content in water will have a negative user acceptance.

(6) Hardness

Total hardness is defined as the concentration of Calcium and Magnesium and is expressed in mg $CaCO_3$ / lit. The ISI guideline is based on taste and household considerations. The desirable value of hardness for drinking water is 300 mg/l of $CaCO_3$.

The consumption of soap in hard water is more. Also hard water can cause scaling in cooking utensils. Hence people may reject water sources with high hardness for washing and cooking.

Table 3.5: Hardness Classification of water

Hardness of water in mg/l of $CaCO_3$	Water Classification
< 50	soft
50 - 150	moderately hard
150 - 300	hard
> 300	very hard

(source : Tchobanoglous and Schroeder, 1985)

(7) Chloride

Chloride is one of the minor constituents of the materials forming the earth crust, it is a major dissolved substance in some natural waters.

Chloride concentration in ground water may be either due to sea water intrusion, or due to the constituents of chloride rich sedimentary rock or due to pollution.

Chloride ion is very difficult to remove from water since it remains in solution through most of the processes that separate other ions. In water, chloride concentration in excess of 250 mg/l may impart a salty taste. But the threshold of detection varies with the individual. In some situations, chloride may accelerate corrosion of pipes and utensils. Hence high concentration of chloride may result possible rejection of water source.

3.3.6. Pump environment

The factors considered in assessing this indicator are broken platform, broken drain and stagnant pools of water near by. Poor drainage facilities and stagnant pools of water near by the handpump may force the people to reject the new facility.

A study conducted on 144 dug wells and 6 handpumps in the State of Kerala in India by the State Pollution Control Board reports that the presence of fecal coliform were detected from the handpump water sample in which the platform of the handpump was physically damaged (KSPCB, 1991).

3.3.7. Condition of pump

Poor pump conditions such as more play of handle, damaged bearings and leaking water tank may reduce the easiness of operation which may result a lower discharge from the handpump. Moreover the damaged bolts, signs of corrosion may result the lower interest of the people and may cause possible rejection of the source.

3.3.8. Community involvement

Acceptance of a handpump by a community is by no means assured. The users may not be satisfied by the supply provided, if it does not meet their expectations. Too often, the people who are to benefit from the handpump are not consulted on matters of construction, use and maintenance of the facilities. It is difficult, if not impossible to achieve the continuous use of a handpump without some degree of community involvement. If handpumps are not accepted and supported by the community, they are likely to suffer from misuse, pilferage or even vandalism.

Organizational experience may be apparent since most communities in the developing countries need assistance with the construction and maintenance of wells with handpumps, but they must be encouraged to participate to the maximum extent possible. Too often, an improved water supply has been seen as a free service that the government must provide to improve the life of its citizens. While many communities may need financial help, relegation of their role to that of recipients without significant participation has often resulted in an inappropriate choice of technology and service level, wrong location of water point, unnecessary high cost, inability to keep the scheme operating, and ultimately user rejection. Community participation that is limited to contribution of free labour results in nothing more than a small cost saving, without addressing other crucial issues. Strong community initiative is essential for the successful long-term maintenance of handpumps, and to achieve it, community members must be intimately involved right from the planning stage.

Chapter 4

Methodology

Research in social science is the direct outcome of man's urge to understand his society, its nature and working. Thus, in social research, the role of social element is very crucial. Human beings are attached to their society. They do not operate under controlled conditions; on the contrary they are always under the diverse influences such as environmental, physical and social and these influences freely interact with each other and seldom operate in isolation. This interplay of diverse influences makes social phenomena more complex. It is again further increased by the uniqueness of each individual's behavior in thinking, working and attitudes (Sadhu and Sing, 1996).

Even with these social complexities, some set patterns of living can be observed within the societies. Individual human being may be unpredictable. But collectively they tend to be reasonably good. Advance in mathematical techniques and its application in social research methods has considerably increased the accuracy of prediction (Sadhu and Sing, 1996).

Application of mathematical techniques need a representative sampling among the total. It is very important that the selected sample should represent the true picture of the study area. The method of stratified random sampling has been adopted in the present study. This procedure of sampling refers to the drawing of samples of known sizes from different strata into which a population is divided before drawing the sample. The samples are drawn in a random fashion. The population is stratified to make the sample representative and hence to increase the provision of the sample estimates.(Sadhu and Sing, 1996).

This chapter deals with the methodology adopted for the present study. It starts with the list of indicators selected for the present study. The further section explains the criteria adopted for selecting the three panchayaths for the study, with a short description of each panchayath. Then its presents the methods adopted for sample selection and also gives an idea about how the study was organized in Palakkad. Finally it covers the methods and the techniques adopted for data collection through observations and interviews. The last part deals with the experiment procedures adopted in the study.

4.1. Indicators selected for the study

The indicators selected for functioning and use of handpump schemes are given separately in the following sessions. In the present study more emphasis is given for use of handpump schemes and hence the indicators selected for functioning in the present study have a relation with the use of handpumps.

4.1.1. Functioning of handpumps

The previous chapter describes the relationship of each of the indicators selected for the present study with handpump functioning in detail. The indicators considered for the present study are;

① Pump discharge,
② Leakage,
③ Breakdown frequency,
④ Average downtime,
⑤ broken and badly constructed platform, and
⑥ water quality.

Even though the maintenance system may affect the functioning of handpumps, the same was not able to cover in the present study due to limitation of time for the data collection. Hence this study limits the reasoning for functioning of handpumps.

4.1.2. Use of handpumps

The indicators selected for the study are;
① number of persons using the handpump,
② volume of water collected per day per capita,
③ distance of handpump from household,
④ presence of alternative sources,
⑤ water quality,
⑥ pump environment, and
⑦ condition of pump.

The effect of community involvement in the user acceptance of a handpump has not been covered in the present study due to the shortage of time.

4.2. Selection of Panchayaths

Information about the various handpump programmes in Palakkad district, the geographic location of the areas in which handpumps have been used extensively, the climatic conditions of these areas etc. were collected in the beginning from the Division office of KWA at Palakkad. In general, the district can be divided into three areas such as,

1. Tribal areas in hilly terrain,
2. Plain areas with perennial water sources, and
3. Plain water scarce areas.

The Grama Panchayaths in Palakkad district vary widely according to their size, elevation, location, geography, water resources, climatic factors etc. A good picture of Palakkad district can be achieved by selecting one Panchayath from each of the above said areas. Accordingly, three

Grama Panchayaths were selected. They are Agali, Sreekrishnapuram and Kozhinjampara respectively.

4.2.1. Agali Panchayath

This Panchayath is located at about 80 kms from the Palakkad town. It consists of two villages, namely Agali and Kallamala. The boundaries of this Panchayath are, the Bhavani River in the north, the Siruvani River in the east and the Mannarkkad Panchayath in the south and west. The Panchayath comes under the Attappadi Community Development Block, the headquarters of which is situated in Agali. About 39% of the total population are Scheduled Tribes. The literacy rate is 60%. The Attappadi Block is popularly known as a tribal block. The main Government institution in this area is the Integrated Tribal Development Programme Office which coordinates majority of the public works in this area.

There are no major industries in this panchayath. Agriculture is the main income generation activity. The topography of the terrain is hilly with an average overburden soil thickness of 0 to 15 metres. In the past, this area was covered with dense forests. Due to massive deforestation, many of the traditional perennial natural streams runs dry during summer. Average annual rain fall is 900 mm. The temperature varies from 23^0C to 33^0C.

There are two piped water supply schemes run by KWA in the panchayath, with river as the water source. This scheme covers only a few portion of the Panchayath, especially the areas near the town centre. One of the main sources of rural water supply is the handpumps fitted with borewells. The two major rivers which are forming the boundaries of this Panchayath caters much of the water demands in the rest of the rural areas, including the water demand for irrigation.

The tribals in Agali live in a typical hamlet (cluster of houses) called "ooru". An ooru may contain 20 to 100 households, placed very close to each another, the same pattern cannot be find in any other parts of the Kerala State. This is very typical for Agali Panchayath.
(source : Development Plan, Agali Grama Panchayath, 1996)

4.2.2. Sreekrishnapuram Panchayath

The Panchayath is situated in the north-west side of Palakkad town. The boundaries of this Panchayath are, the Karimpuzha River in the north, the Pookkottukavu Panchayath in the south, the Vellinezhy Panchayath in the west and Kadampazhipuram Panchayath in the east. The economy of the Panchayath is based on agriculture.

The major surface water source is the Karimpuzha River. There are six natural streams in the Panchayath which run dry during extreme summer. There is also a piped water supply scheme run by KWA in the Panchayath, benefitting only 600 people, near the town centre. The housing pattern is scattered, with most of the houses own individual dug wells. Thirty two public dug wells (owned by Panchayath), 100 private ponds and 13 public ponds are spread out in the

panchyath for meeting the water demand of rural people. A recent survey conducted by the Panchayath reports that about 80% of the people depend dugwells as their water sources.
(source : Development Plan, Sreekrishnapuram Grama Panchayath, 1996)

4.2.3. Kozhinjampara Panchayath

This panchayath is situated in the eastern side of Palakkad district. The boundaries of this panchayath are the Vadakarappathy Panchayath in the north, the Perumatti Panchyath in the south, the Ezhuthenpathy Panchayath and the State of Tamil Nadu in the east and the Elappully and Nalleppilly Panchayaths in the west. In general the land is plain, with a gentle slope towards the western side. The temperature varies from 26^{0}C to 42^{0}C. Majority of the people speak Tamil which is the mother tongue of the nearby State, the Tamil Nadu.

This area is one of the most drought affected areas in the Palakkad district. It is reported that in extreme summer, in many places, the public have to depend the water conveyed through lorry, even for drinking purposes. There are about 6 small piped water supply schemes in the panchayath run by Kerala Water Authority with borewell water as source. In addition to this, there are about 50 public wells, 1300 private dug wells and 50 borewells in the Panchayath for meeting the water demand of the rural people. Another 300 private borewells were drilled for meeting the irrigation demands.
(source : Development Plan, Kozhinjampara Panchayath, 1996)

The other details pertaining to the panchayaths are given in the following table.

Table 4.1 : General information about the selected Panchayaths

Name of Panchayath		Agali	Sreekrishnapuram	Kozhinjampara
Location with respect to Palakkad Town		North-East	North-West	East
No. of wards		13	9	11
Population as on 1996	Total	33693	18610	29103
	Scheduled Caste	3031	3710	3010
	Scheduled Tribe	9209	0	867
Population density per sq.km		106	629	664
Average number of persons per household		4.7	4	4.6
Area in sq. km.		310	29.6	43.84
No. of borewells with handpumps		55	28	50
General topography of the area		Hilly terrain	Plain	Plain
General source for water supply in rural areas		River, HP, streams	Dug wells, streams, ponds	HP, Piped Water Supply
General conditions		WTD	WTS	WTD

WTD - ground water table deep, traditionally drought prone area, scarcity of water in all seasons
WTS - ground water table shallow, scarcity of water in summer season, HP - Handpump system

4.3. Sample selection

It is evident from the previous section that the Panchayaths in Palakkad differ in their traditional water sources, terrain, its proximity towards droughts, rainfall, population density, distribution pattern, etc..

Information on the number of handpumps, public dug wells, ponds etc. has been collected from the respective panchayaths. This has been obtained either from official records of panchayaths, or by meeting key personnel, or in some cases even by short visits. The complaints received from the public especially on bad taste and discolouration of food were also noted during these visits. Two wards from each of the three Panchayaths were considered for the present study. The criteria for the selection of a ward included:

(i) *should contain at least three borewell with handpumps* :
This number has been limited by considering the time available for the data collection.

(ii) *with and without the presence of iron* :
As discussed above, during the initial field visits, complaints received from the public especially on taste, food discolouration etc. gave a preliminary information regarding the presence of iron.

(iii) *availability and non-availability of traditional water sources* :
The preliminary information regarding the presence of a traditional water source near by was also collected from the panchayath authorities and sometimes even during the initial field visits.

The sample size varied from section to section of this study and is indicated in the respective sections.

4.4. Organizing Works

Organizing a field study in Palakkad with limited communication and traveling facilities was extremely difficult. Persons of different interest, political, financial and communal back ground have to be dealt with. The rural people also felt that a study like this may have been politically motivated. So in some places, be prepared to cooperate with the study.

Full cooperation of the key personnel was necessary for the efficient data collection. Hence it was decided to get the cooperation of this key persons from the selected areas, right from the beginning of the study. Some of them were ward members(those who represent the ward in the Panchayath governing body), some of them were school teachers and some others were panchayath officials . An appointment with these key persons were made in advance. Then, the purpose, the relevance and the proposal for carrying out such a study was explained to them. It was made very clear in the beginning itself that for the time being the author did not represent KWA, and this study is being conducted as a part of author's training programme which has to be completed in the Netherlands.

A field visit was arranged with the key personnel in the beginning. A location map of handpumps of the concerned ward is prepared with the help of public in the presence of key personnel. The map includes the roads, handpump schemes and the public dug wells in the ward. This idea was basically to find the location of borewells and other sources in the area.

4.5. Observation Procedure

After getting sufficient information on location of handpumps and its accessibility from the main roads, the field work was arranged.

4.5.1. Sample size

Each handpump is taken as a sample in the observation procedure. The details of samples selected under each Panchayath is given below.

Table 4.2 : Details of samples taken for observation

Name of Panchayath	Agali		Sreekrishnapuram		Kozhinjampara	
Ward No.	X	XI	V	VI	III	X
No. of samples	4	3	3	3	3	4

4.5.2. Observation method

An observation sheet was prepared in the beginning which included information on the number of households within a radius of 250 metres, the pump discharge, the leakage, the condition of handpump and the condition of platform and drainage facilities. A copy of observation sheet is attached in appendix I.

A water resource mapping for each handpump location under study was prepared with the help of community members. The map included the location of households, and the locations of existing water sources such as community wells (perennial / seasonal), springs (perennial / seasonal), rivers and streams (perennial / seasonal), ponds (perennial / seasonal), and piped water supply. Different notations were given for each of these sources which is attached in appendix IV. The number of households within a radius of 250 metres was also marked in the map.

For measuring the pump discharge, a bucket of 15 litre capacity was used. Pumping rate was kept constant at 50 strokes per minute. The number of strokes required to fill this bucket is counted and is noted in the corresponding sheet. This number can be compared with literature for finding the actual discharge of the pump.

For assessing the leakage of handpump the following procedure has been adopted. Pumping was started after waiting for five minutes. If the pump was able to deliver water within the first three strokes of pumping, it was considered as a non-leakage handpump. Then it was directly noted in the observation sheet as whether the pump is leaky or not.

Condition of handpump was assessed as follows. A total of seven factors such as play of the handle more than 3 mm (3 millimetre clearance was given in the approved design of India Mark II handpump as per IS 9301), clear signs of corrosion, loose bolts, lacking grease in chain, damaged top cover, damaged bearings and leaking water tank were studied in detail. These were recorded in the observation sheet. 'Yes' or 'No' option was given to each of these items. One 'No' out of seven was considered 'good'. Two to Three 'No's out of seven was considered as 'moderate' and the rest as 'bad'. This approach was based on the approach followed by Lloyd and Helmer for water quality surveys (Lloyd and Helmer, 1994).

The same method was adopted for measuring the condition of platform and drainage facilities. A total of four items were considered for the evaluation. They were stained platform, broken platform, broken drain and stagnant pools of water nearby. 'Yes' or 'No' option was given to each of these items. One 'No' out of four was considered 'good'. Two 'No's out of four was considered 'moderate' and the rest as 'bad'.

4.6. Interview Procedure

It was proposed to conduct an interview among 9 households residing in each handpump location within the stipulated time for data collection. From the literature on the use of water facilities, it has been found that, the distance to the source was an important criteria for user acceptance. Hence, it was decided to make a stratified random sampling on the selection of households for interview. Accordingly three households within a radius of 50 metres, three from 50 to 100 metres and three from 100 to 250 meters in each handpump location were interviewed in general.

4.6.1. Sample size

In general, nine households from each handpump location were interviewed with a preset questionnaire. In some locations, it was difficult to meet this requirement of getting nine, either due less number of households or due to uneven spread out of households in the location. In the former case, all households within a radial distance of 250 metres were interviewed. In the later case, again nine households were selected with a view to cover five near the traditional water source and four near the handpump. A total of 178 house holds were interviewed. The Panchayath wise details are given below.

Table 4.3 : No. of households interviewed

Name of Panchayath	Agali		Sreekrishnapuram		Kozhinjampara	
Ward No.	X	XI	V	VI	III	X
No. of samples(households)	36	25	27	27	36	27

4.6.2. Interview Method

The interview was carried out with a pre-prepared questionnaire which is attached in appendix II. A source-use matrix is also prepared and is attached in appendix III. A small booklet consisting of one observation sheet, nine questionnaire sheets and one source-use matrix sheet were made in the beginning.

The main objective was to collect information regarding the number of persons using the handpump, the volume of water collected per day per household, the distance of handpump from the household, the perception on the quality of the handpump water on taste, color, odor etc., the average breakdown frequency of handpumps, the usual downtime, and the general use of handpump systems.

The average number of persons using the handpump was obtained from interviews. It was also possible to clarify the total number of persons within a locality from the water resource map by considering an average family size for the respective panchayaths.

In the rural areas of Palakkad, normally people use a standard ten litre plastic pot for the collection of water from handpumps. The households were asked for the number of pots of water they collected from a handpump in a day and the same has been recorded in the interview sheet. Also the number of persons in each household were noted. The consumption rate then can be calculated.

The distance to the handpump from the household was obtained from the water resource map and is recorded in the interview sheet. The households were also asked about their perception on taste, color, odor etc. of handpump water and were recorded in the interview sheet. They were also asked about the breakdown frequency of handpumps and were recorded as either often(every monthly), or regularly(once in three months) or occasionally(once in six months) and the same was marked in the sheet. There was no provision made in the prepared questionnaire for handpumps which have not failed at all (means which are still working after the erection). Few such types of handpmps were came across the study and were recorded separately. The households were also interviewed for the usual downtime in handpump systems, the agency responsible for doing the maintenance works and the availability of local mechanics for carrying out such repair works.

The households were interviewed for their water sources for domestic purposes such as drinking, cooking, washing, personal hygiene, gardening and cattle feeding and each response were marked in the attached source-matrix sheet then and there The possible reasons for the general non-usage of handpump systems such as more distance, water taste salty, colored, having foam, having odor etc. were also listed in the source-matrix sheet. The household's responses for non-use of handpump for a specific purpose was noted and recorded in the source matrix sheet.

4.7. Experimental Works

As part of this study, the water quality of borewell water samples from the selected areas has to be tested. The parameters included turbidity, pH, total hardness, iron and chloride. Kerala Water Authority(KWA) has recently started a district laboratory at Palakkad for monitoring the quality of water supplied through its piped water supply schemes. The lab is in its initial stages of working and only limited facilities were available for testing. There was no facility for testing iron. The nearest KWA lab for testing iron was in Thrissur, approximately 65 kms from Palakkad. The laboratory at Thrissur is well equipped and properly staffed for conducting water quality analysis. The workload for this lab was also high. Hence, for most of the times, an appointment with the lab officials was necessary for carrying out tests.

Water samples from handpumps and the mostly used traditional sources in each ward are collected for testing by following standard procedures. The details of water samples taken from the three panchayaths are given below.

Table 4.4 : Ward-wise details of the number of water samples taken for testing

Name of Panchayath		Agali		Sreekrishnapuram		Kozhinjampara	
Ward No.		X	XI	V	VI	III	X
No. of samples	handpump schemes	4	3	3	3	3	4
	dug well water	2	1	3	2	1	2
	river water	0	1	0	0	0	0

The water samples are then transported to the lab at Thrissur on the same day of collection. They were analyzed within 24 hours for the physical and chemical parameters. The procedure adopted for taking water samples and the methods adopted for carrying out tests were according to the Indian Standards IS : 3025.

Chapter 5

Results

This chapter begins with the description of differences in the selected study area. Then it provides the information on the pump conditions in Palakkad. Further it reviews the various factors affected the service level in Palakkad with a short description of each item. Then it presents the review on available alternate sources in each selected Panchayaths in the area. Then it continues with the review on water quality of the handpump water samples and the water samples collected from the selected traditional water sources.

5.1. Description of differences in the selected area

The Grama Panchayaths in Palakkad varies widely according to their size, elevation, location, geography, climatic factors, traditional sources, rainfall *etc.*. In this chapter, some of the factors which may affect the use of water facilities are specifically considered.

Table 5.1 gives the factors which might have affected the use of the handpump water supplies. The topography of the terrain may have an effect on the water availability in the dug wells, especially in Agali Panchayath. As from the table below, it can also notice a wide difference in the handpump density in Agali Panchayath and this might have been one of the reasons for the heavy usage of handpumps in the Panchayath.

Except in Agali, almost all area of the other two Panchayaths are either covered with dug wells, ponds or even by piped water supply schemes. It is understood from the population density and the area covered by each handpump in Agali, the settlements or the hamlets (called *Ooru*) are isolated.

Table 5.1 : Differences in the selected areas

Name of Panchayath	Agali	Sreekrishnapuram	Kozhinjampara
General topography of the area	Hilly terrain	Plain	Plain
Population density per square kilometre	106	629	664
Handpump density in number of handpumps/sq. km.	0.18	0.94	1.14
No. of piped water supply schemes run by KWA	2	1	6
Ground water table	Deep	Shallow, can be tapped in top soil	Deep
Scarcity of water in all seasons	Yes	No	Yes
Thickness of overburden soil	0 - 20 m	6 - 19 m	6 - 21 m
Static water level in the borewell	10 - 18 m	5 - 16 m	10 - 18 m

5.2. Review on Handpump Systems

The sustainability of a handpump based water supply depends on condition of the pump itself. The pump conditions as well as the pump environment may affect the long term functioning of the handpump systems. To review the condition of the handpump system, the study looked into the following parameters.

① pump discharge
② leakage
③ the breakdown frequency
④ the average downtime
⑤ the pump conditions, and
⑥ the pump environment

5.2.1. Pump Discharge

Pump discharge is one of the most important factors in the selection of a type of handpump. The observations obtained from field tests in developing countries is that when users are able to compare different pumps under the same operating conditions, they almost invariably favoured the pumps with highest discharge rate, eventhough the force required may be relatively high. In extreme cases, the community may reject pumps which produce low discharges, irrespective of the efforts applied (Arlosoroff et al, 1987).

In the present study area, there was no choice of the selection of any other handpump type except the India Mark II pumps. A total of twenty handpumps were tested for the discharge rate. The field testing of the handpumps were done at a pumping rate of 50 strokes per minute. The Indian Standard Code IS 9301 specifies a stroke rate of 40 per minute for the testing of handpumps. As the discharge from a reciprocating pump is directly proportional to the stroke rate, i.e. the number of strokes per minute, the calculated discharge at 50 strokes per minute can be directly converted to get the pump discharge at a stroke rate of 40 strokes per minute.

In one particular case, i.e. near Nagaliyamman Covil road in ward X of Kozhinjampara Panchayath which is coded as HP17, the leakage in the pipe was enormous. No water was delivered from this pump at a stroke rate of 50 strokes per minute and hence the discharge of this pump at this stroke rate is considered to be zero. A trial pumping has performed on the same pump at a stroke rate of 90 strokes per minute yielded a discharge of 7.2 litres per minute.

The number of strokes taken to pump 15 litres of water at a stroke rate of 50 strokes per minute is given in appendix VI. The discharge of each handpump at 50 strokes per minute and 40 strokes per minute is calculated and are presented in the same appendix. The table below gives a comparison of the minimum, maximum and average discharges in the three Panchayaths in Palakkad.

Table 5.2 : Discharge of handpumps in different Panchayaths.

Area	Discharge in litres per minute			
	Minimum	Maximum	Average	Standard deviation
Agali Panchayath	8.5	16.0	12.3	2.1
SreekrishnapuramPanchayath	10.6	15.7	12.3	1.6
Kozhinjampara Panchayath	0.0	15.0	9.4	3.4
Palakkad district	0	16.0	11.3	3.3

It can be seen from the pump discharge table, the average value of pump discharge is slightly less than the standards set up by the bureau of Indian Standards. From the appendix VI, it can be found that 55% of the pumps produced a lesser discharge than the standard and 20% of the handpumps visited yielded a discharge of less than 10 litres per minute.

5.2.2. Leakage

Leakage, mainly caused by defective or loosened couplings, due to rusted and perforated rising mains, or due to piston seals damages *etc.*.can reduce the discharge of the pumpset.

In the present study five out of a total of 20 handpumps were found to be leaky. The details are given below.

Table 5.3 : Number of leaky handpumps in different Panchayaths.

Area	No. of leaky handpumps	No. of non-leaky handpumps	Total
Agali Panchayath	2	5	7
Sreekrishnapuram Panchayath	0	6	6
Kozhinjampara Panchayath	3	4	7
Palakkad district	5	15	20

The leakage is more in Agali and Kozhinjampara Panchayaths where the handpump use is more when compared to Sreekrishnapuram Panchayath. It is interest to note that the average discharge of handpumps in Kozhinjampara Panchayath is less than the standards and this may be due to the excessive leakage of pumps in this area.

5.2.3. Breakdown frequency

In Palakkad, the handpumps are handed over to the Panchayaths for operation and maintenance. Opinion about the breakdowns in handpumps is obtained from the field interviews. A total of 178 households were interviewed in the present study.

The opinion obtained from all handpump users were recorded in the appendix VII. The number of handpump users is given in table 5.4. For the purpose of tabulating the data, any household collecting water from the handpump for any purpose in any season of the year is considered as a handpump user.

Table 5.4 : No. of interviewee households covered in different Panchayaths.

Area	Handpump users	Handpump non-users	Total
Agali Panchayath	38	23	61
Sreekrishnapuram Panchayath	33	21	54
Kozhinjampara Panchayath	52	11	63
Palakkad district	123	55	178

The breakdown frequency in handpumps is given below.

Table 5.5 : Number of handpumps based on breakdown frequency.

Area	once in 3 months	once in 6 months	more than 6 months	total
Agali Panchayath	1	3	3	7
Sreekrishnapuram Panchayath	1	4	1	6
Kozhınjampara Panchayath	0	6	1	7
Palakkad district	2	13	5	20

Eventhough a slight variation in household response is obtained, in general per pump, the picture was reasonably uniform.

5.2.4. Downtime

The average downtime of each handpump ıs obtained by interviewing the beneficiary households. A total of 119 handpump users of 20 handpumps were covered in the present study and the details were given in the table 5.4. above.

The handpump coded HP5 in Adiyakkandiyoor in ward XI of Agali Panchayath and HP11 at Pattathilppadi in ward VI of Sreekrishnapuram Panchayath are still working without any failure since erection in 1989. The opinion of the downtime of the handpump users in these two locations were marked under the downtime of *less than one week.*

Users response per handpump were very close to each other, which give the impression that the time of repairing the estimate is reasonably accurate. The time taken for different pumps to be repaired is tabulated ın table 5.6.

Table 5.6 : No. of handpumps based on downtime

	Downtime in handpumps			
Area	1week	2 weeks	3-4 weeks	total
Agali Panchayath	1	6	0	7
Sreekrıshnapuram Panchayath	2	1	3	6
Kozhınjampara Panchayath	2	1	4	7
Palakkad district	5	8	7	15

From the above table, a difference in average downtime can be noticed for the three Panchayaths. This is due to the fact that in Palakkad, the operation and maintenance of handpumps are carried out by the concerned Panchayaths. An average downtime of two to three weeks together wıth a breakdown frequency of once ın six months may lead the handpump idle for one to two months a year. Hence on an average, the total downtime in a handpump in Palakkad comes to about one month in a year.

5.2.5. Pump Conditions

A total of seven factors were considered for reviewing the pump conditions. The responses for each of the seven items were separately marked for handpump locations and is presented in appendix VI. A rating has been given for the overall condition of the handpump. The methods adopted for assessing the rating were described in the previous chapter.

Table 5.7 : The no. of handpumps based on pump conditions in Palakkad District

Sl. No.	Factors considered	Observation		Total
		Yes	No	
1	Play of handle more than 3 mm	6	14	20
2	Clear signs of corrosion	2	18	20
3	Bolts loose	2	18	20
4	Lacks grease	19	1	20
5	Top cover damaged	2	18	20
6	Damaged bearings	3	17	20
7	Leaking water tank	3	17	20

From the above table, it can be seen that about 30% of the handpumps visited in the area were having a handle play of more than 3 mm. Of these handpumps, majority were from the Kozhinjampara Panchayath, where the usage of handpump was more. Also about 95% of the handpumps covered were lacking greasing of the handpump chain which was a simple preventive maintenance to be carried out in India Mark II handpumps. This implies that the community involvement in handpump maintenance in the study area was very less.

Based on the above seven factors given in table 5.7, a rating has been arrived for the whole twenty handpumps in the study area as '*Good*', '*Moderate*' or '*Bad*' as defined in chapter four. The table below gives the rating of handpumps based on the pump conditions.

Table 5.8 : No. of handpumps based on pump conditions

Area	Rating			Total
	Good	Moderate	Bad	
Agali Panchayath	6	1	0	7
Sreekrishnapuram Panchayath	3	2	1	6
Kozhinjampara Panchayath	2	2	3	7
Palakkad	11	5	4	20

Majority of the *bad* handpumps were identified again in the Kozhinjampara Panchayath, where the average number of users per handpump was the largest among the other two Panchayaths. One of the reasons for the majority of *bad* handpumps may be the more percentage of leaky handpumps in the Panchayath.

5.2.6. Pump Environment

The factors on condition of pump environment covered in the study are

① whether the platform is broken,
② whether there is a stained platform,
③ whether the drain is broken, and
④ whether there is a stagnant pool of water near by.

The details of each handpump location are presented in appendix VI. The abstract is given below.

Table 5.9 : No. of handpumps based on pump environment in Palakkad district.

Sl. No.	Items considered	Observation		Total
		Yes	No	
1	Stained platform	14	6	20
2	Broken Platform	8	12	20
3	Broken Drain	6	14	20
4	Stagnant pools of water near by	13	7	20

Most of the stained platforms noticed were in Agali and Sreekrishnapuram Panchayaths. In these Panchayaths, the average number of users per handpump was less than the users per pump in Kozhinjampara Panchayath Most of the stagnant pools of water was noticed in Agali and Kozhinjampara Panchayaths, where the handpumps were heavily used.

A rating has also been arrived for the failure or damages to the environment of the pump as defined in chapter four. The table below gives the rating of the twenty covered handpumps in different Panchayaths in the Palakkad District.

Table 5.10 : No. of handpumps based on pump environment in different Panchayaths.

Area	Rating			Total
	Good	Moderate	Bad	
Agali Panchayath	2	1	4	7
Sreekrishnapuram Panchayath	5	1	0	6
Kozhinjampara Panchayath	2	2	3	7
Palakkad	9	4	7	20

From the above table, it can be seen that most of the handpumps in Agali and Kozhinjampara had a *bad* conditioned platforms and drainage facilities.

5.3. Review on Service Level

An estimate of the benefits provided by each technological solution for water supply may be useful in comparing the different technological solutions chosen for water supply in a particular area. Normally the amount of benefits provided by a new option can not be assessed exactly. The scale of influence by a new water facility is normally affected by the two key technical factors. - the "service level"(i.e. the distance water must be hauled from the water point to the dwelling , queuing plus filling time fro each water hauler and the ease of drawing water); and the "reliability" the water is available at the water point when needed.

The indicators considered in the present study are

① the average number of users per handpump,
② the average volume of water collected per capita per day , and
③ the average distance of household from the handpump.

5.3.1. The Average Number of Users per Handpump

The average number of persons covered by a handpump is obtained as follows. During the interviews, an average of nine households were covered in each handpump location. Of these nine, some households were absolutely non-users of handpumps. The percentage of handpump users out of the total of nine households for each location for drinking and cooking is calculated. Percentage of handpump users for washing and bathing is calculated separately. The average number of handpump users has been arrived by giving a weightage of one out of three for drinking and cooking and two out of three for washing and bathing. The waited percentage thus obtained is multiplied by the average number of persons residing within 250 metres radius gave the number of users per each handpump for a particular location. The minimum, maximum and average number of users per handpump in each Panchayath is noted below.

Table 5.11 : Average number of users per handpump in different Panchayaths

Area	number of persons per handpump			
	minimum	maximum	average	standard deviation
Agali Panchayath	0	132	46	46
Sreekrishnapuram Panchayath	1	71	19	19
Kozhinjampara Panchayath	24	185	63	51
Palakkad District	0	185	45	47

From the above table, it can be understood that the average number of handpump users varies widely in the three different Panchayaths in the study area.

From the literature, it has been found that the waiting time may indirectly affect the number of persons benefitted from the handpump. Data were collected on the average waiting time in each selected area from the household interviews. Household were approached with the following questions

① which is the peak hour of water collection ?
② is there any queue during the peak hour of water collection from handpumps ?
③ is there any waiting needed to collect water and if so what is the usual waiting time ?

The response for each of these questions are given below.

Table 5.12 : No. of households based on peak hour use

Area	Number of house holds		Total
	Morning 6AM - 8AM	Evening 4PM - 8PM	
Agali Panchayath	33	5	38
Sreekrishnapuram Panchayath	26	3	29
Kozhinjampara Panchayath	48	4	52
Palakkad District	107	12	119

Majority of the handpump users in the study area collect handpump water in the morning.

The details of waiting time obtained from interviews were given in the appendix VII. The abstract of the response of handpump users were given in the accompanying table.

Table 5.13 : No. of handpumps based on waiting time near the pump

Area	Number of handpumps				Total
	< 10 minutes	10-15 minutes	15-30 minutes	> 30 minutes	
Agali Panchayath	3	2	2	0	7
Sreekrishnapuram Panchayath	5	0	0	1	6
Kozhinjampara Panchayath	0	5	1	1	7
Palakkad District	8	7	3	2	20

Eventhough a difference of response from households on waiting time is obtained, again per pump the response was more or less uniform.

5.3.2. Average Volume of Water Collected per Capita per Day

The households were asked for the total collection of water either from the handpump or from the traditional source. When they use both, the water collected only from the handpumps were recorded. The details of field data obtained are tabulated as follows.

Table 5.14 : The average volume of water collected in lpcd per handpump

Area	Average volume of water collected per litres per capita per day		
	Minimum	Maximum	Average
Agali Panchayath	8	50	20.4
Sreekrishnapuram Panchayath	12	33	20.5
Kozhinjampara Panchayath	13	100	27.5
Palakkad District	8	100	22.9

The above table illustrates that the volume of water collected from a handpump in Kozhinjampara Panchayath are more than that from the other two Panchayaths. A possible explanation for this is that in this Panchayath, the accessibility to the river water is limited. In other Panchayaths, there are perennial rivers near by the study area and people used to wash their clothes and take bath in these rivers and hence a less usage of water. Moreover, the handpumps in this Panchayath may be nearer to the households than the other two.

5.3.3. Average Distance of Household from the Handpump

The distance observed in the field are recorded in the appendix VII. The minimum, maximum and average of the distances recorded in the appendix were presented in the following table.

Table 5.15 : The average distance of households from the handpump

Area	Average distance between household and handpump in m		
	Minimum	Maximum	Average
Agali Panchayath	10	280	109
Sreekrishnapuram Panchayath	10	250	133
Kozhinjampara Panchayath	5	200	89
Palakkad District	5	280	109

From table 5.15, it can be understood that the average distance between the handpump and the household is the minimum in the Kozhinjampara Panchayath. It may also important to note that the population density in this Panchayath is the highest among the three Panchayaths selected for the study.

5.4. Review on Available Alternate Sources

In general, the available alternative water sources in the study area are;

① Public Dugwell
② Private Dugwell
③ River Water
④ Pond Water
⑤ Stream Water, and
⑥ Piped Water

To enter the data in appendix VII, different notations have been used for Public and Private dugwells.

The following table gives the details of use of available water sources in Palakkad district for different purposes in the dry and wet season. The table is based on interviews with 178 households. The response related to cattle feeding only apply to 116 households with cattle.

Table 5.16 : Use of different water sources in Palakkad District (n=178 households)

Source	Number of households													
	Drinking		Cooking		Washing		Bathing		Per. Hygiene		Gardening		Cattle feeding	
	D	W	D	W	D	W	D	W	D	W	D	W	D	W
HP	69	64	69	64	73	70	79	75	95	91	107	104	64	63
W1	22	23	22	23	6	8	4	6	14	16	6	8	12	12
W2	70	78	70	78	54	55	51	53	64	66	63	64	40	41
RW	3	3	3	3	22	22	26	26	3	3	0	0	0	0
PW	0	0	0	0	18	18	17	17	0	0	0	0	0	0
SW	1	1	1	1	0	0	0	0	1	1	1	1	0	0
PP	13	9	13	9	5	5	1	1	1	1	1	1	0	0

Codes used for filling the table
HP - Handpump, RW - River Water, PP - Piped Water
W1- Public Dugwell, PW - Pond Water, D - Dry Season
W2- Private Dugwell, SW - Stream Water, W - Wet Season

From the table above, it can be seen that majority of the households use dug well as their preferred water source for drinking and cooking. The priority for handpump comes second. Wherever piped water supply was available, people take water from the standpost only as it can be seen from the appendix VII.

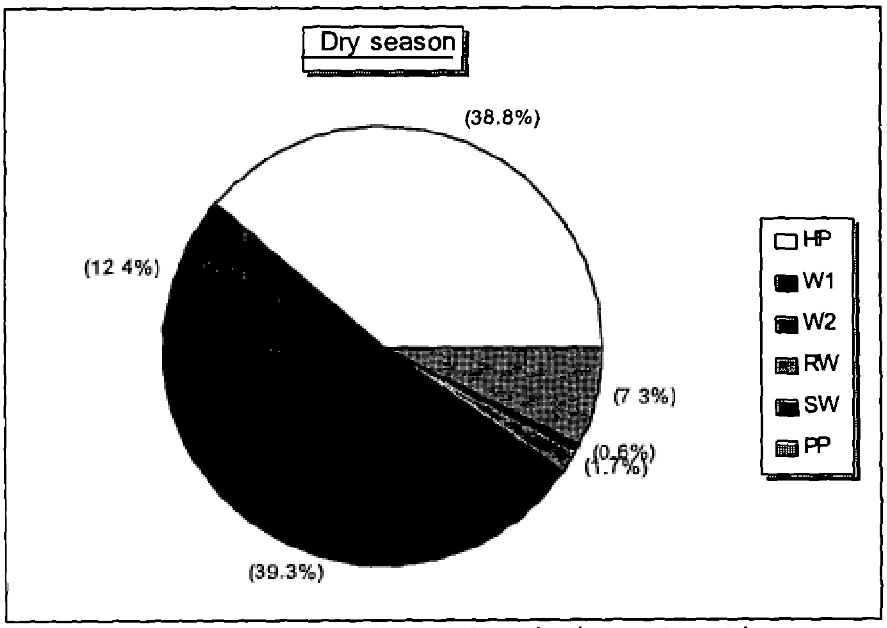


Figure 5.1 sources of water for drinking and cooking

From the above figure, it can be seen that about 52% of the households use dug well (including public and private) as their water source for drinking and cooking in rural areas of Palakkad during dry season. About 39% use handpump as their water source in these areas. This is because in dry season, the owners of the private well only allow the public to draw a limited amount of water from their well for drinking and cooking.

The following table below gives the reasons identified during the field interviews for the non-use of handpumps for each specific use.

Table 5.16 : Number of households responded for non-use of handpump systems in Palakkad district

Reasons for non-using the hand pump	Number of households													
	Drinking		Cooking		Washing		Bathing		Per Hygiene		Gardening		Cattle feeding	
	D	W	D	W	D	W	D	W	D	W	D	W	D	W
TD	77	83	70	75	0	0	0	0	0	0	0	0	0	0
DM	18	16	18	16	18	18	10	11	24	24	23	23	13	13
CW	5	5	8	8	10	10	2	2	5	5	0	0	0	0
HW	7	8	7	8	40	41	45	46	43	45	45	46	31	32
NE	2	2	6	7	10	12	10	12	11	13	3	5	8	8
WR	0	0	0	0	16	16	0	0	0	0	0	0	0	0
WP	0	0	0	0	11	11	0	0	0	0	0	0	0	0
BR	0	0	0	0	0	0	22	22	0	0	0	0	0	0
BP	0	0	0	0	0	0	10	10	0	0	0	0	0	0
Total	109	114	109	114	104	107	99	103	83	87	67	70	52	53

Codes used for filling the table
TD - Water tastes different from the traditional water source
DM - Distance more
CW - Coloured water
HW - Have own private well
NE - Not enough water is available
WR - Traditional practice of washing clothes in river
WP - Traditional practice of washing clothes in pond
BR - Traditional practice of taking bath in river
BP - Traditional practice of taking bath in pond

About 71% of the non-users of handpumps complained about the taste difference of handpump water from the traditional source for drinking and cooking. The second major complaint was the increase of distance to the handpumps. The third preference was given to the colour of the handpump water.
The details are given in the accompanying figure. Refer the above table for notations used.

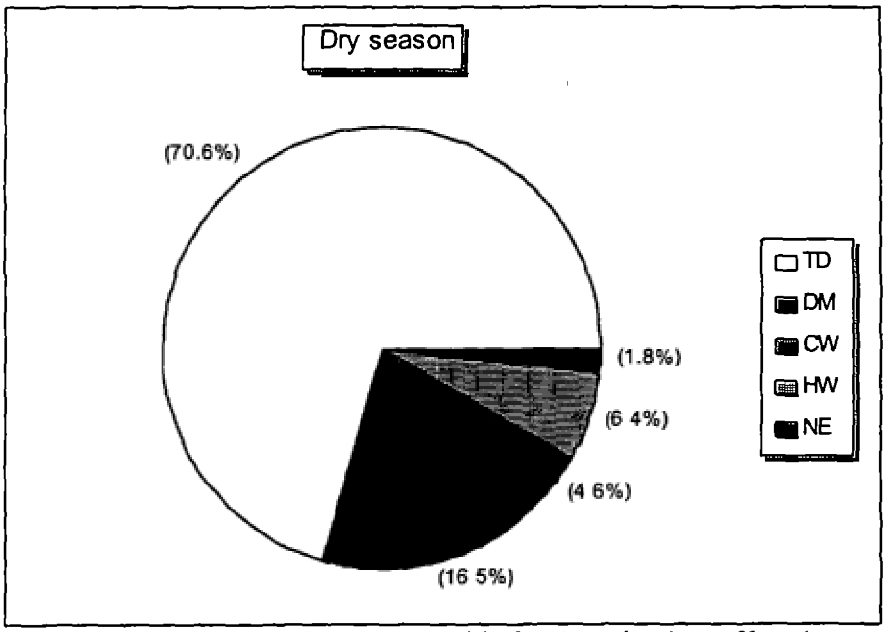


Figure 5.2 Responses of the households for the rejection of handpump water in Palakkad.

5.5. Review on Water Quality

Water samples from 20 handpumps, 11 dug wells and one river has been collected from the selected three Panchayaths in the area. The water samples were tested within twenty four hours of collection. This delay was unavoidable and it may have an effect on the test results in that the measured iron concentration can be somewhat less than the actual concentration. Higher concentration of iron above 0.3 mg/l causes taste to water. In the present study, the idea was to check the relation between the user acceptance and taste of water, thus the determination of the exact value of the iron concentration was not necessary.

The water quality of handpump water may be an important parameter. The test results obtained from handpump water samples and dugwell water samples are presented in the table 5.17. From the table, it can be seen that there is a wide variation of the value of turbidity between the handpump and dugwell water samples. Also a wide variation of the concentration of iron from the dugwell water and handpump water can be found.

It can see from the table that the water quality of the three areas in Palakkad district is different. For example, the values of the total hardness, electrical conductivity, chloride and fluoride are very high than the standards recommended for the drinking water in Kozhinjampara Panchayath. The complaints from the public during the field visit in this area in some of the dugwells are mainly due to the high value of chloride.

Table 5.17 : Test results on water quality parameters of different water sources in the study area

Panchayath	ward	Code	Source	pH	turbidity NTU	EC mS/cm	T.H mg/lCaCO	chloride mg/l	fluoride mg/l	iron mg/l
AGALI		HP1	BW	7.07	5	784	332	31	1.765	0 255
		HP2	BW	6.80	3	655	236	30	1 450	0 235
	X	HP3	BW	6.69	12	511	166	20	1 190	0 520
		DW1	DW	7.00	1	574	168	57	1.050	0 000
		DW2	DW	7 08	1	584	196	23	1 575	0 000
		HP4	BW	6 92	25	606	180	23	1.425	1.015
		HP5	BW	6 86	14	333	128	14	1.055	0 575
		HP6	BW	6.74	210	348	158	12	0 805	2 705
	XI	HP7	BW	6 61	280	255	98	12	0.000	2 902
		DW3	DW	5.78	6	74	16	10	0.630	0 195
		RW1	RW	6.95	2	47	20	16	0.650	0 210
		HP8	BW	6.99	17	203	90	11	1.230	1 000
SREE-		HP9	BW	7.09	28	605	286	10	1.285	2 380
KRISHNA-	V	DW4	DW	6.74	2	84	26	10	0.870	0 060
PURAM		DW5	DW	6.42	5	184	50	13	0 830	0 065
		HP10	BW	6.95	13	306	88	17	0.990	3.740
		DW6	DW	6 65	2	141	50	30	0 880	0.175
		HP11	BW	6 92	170	182	72	14	1 210	3.860
		HP12	BW	6 46	320	168	74	10	0 990	3.630
	VI	DW7	DW	5 40	1	28	4	7	0.880	0 030
		HP13	BW	6.88	27	186	82	12	1.190	1.920
		DW8	DW	5 98	1	78	10	9	0.885	0.085
		HP14	BW	6 52	80	1080	382	90	1.195	3.840
KOZHIN-	III	HP15	BW	7 47	4	1965	670	376	1 380	0.220
JAMPARA		HP16	BW	7 34	3	935	382	85	1 380	0.175
		DW9	DW	7 32	3	592	208	33	1 085	0.000
		HP17	BW	7.24	50	998	356	80	1.740	3.740
		HP18	BW	7 84	4	693	236	48	1 660	0.220
	X	HP19	BW	7.50	6	488	188	35	1.700	0 460
		HP20	BW	6.75	5	407	136	25	1.260	0.255
		DW10	DW	7 28	3	2750	978	453	1.880	0.030
		DW11	DW	7 31	3	596	258	41	1 240	0.050

BW - Borewell
DW - Dugwell
RW - River Water

Chapter 6

Discussions

This chapter provides an overview of the relationship with the indicators selected in the present study for the functioning and use of handpump systems. The chapter starts with the discussion on functioning of handpumps and the relationship of various parameters involved in the present study. Further it explains the relationship of various components with the user acceptance of handpumps in the study area.

6.1. Functioning of Handpumps

The literature reviewed earlier provided the information on the indicators which normally affects the functioning of handpumps. Chapter three explains the possible relationship of those indicators with functioning of handpumps. The following subsections explain the relationship of the indicators selected in the present study with functioning of the system. The functioning of handpumps in this chapter is discussed based on the national standards as discussed in the earlier sections.

6.1.1. Pump Discharge

As per the Indian Standard IS 9301, the discharge rate of an India Mark II handpump should give at least 12 litres per minute at a stroke rate of 40 strokes per minute. In the present study, about 55 percentage of the handpumps came across were found to give less discharge.

The difference in pump discharge may be related to the intensity of use of each pump . So an estimate was made of the average production of each pump. This was done for only 19 pumps as the most leaky with zero discharge is left out. Average production of water from each pump can be obtained by multiplying the average number of pump users with the average volume of water consumption per capita per day arrived for each handpump. Further details on this are provided in appendix VII.

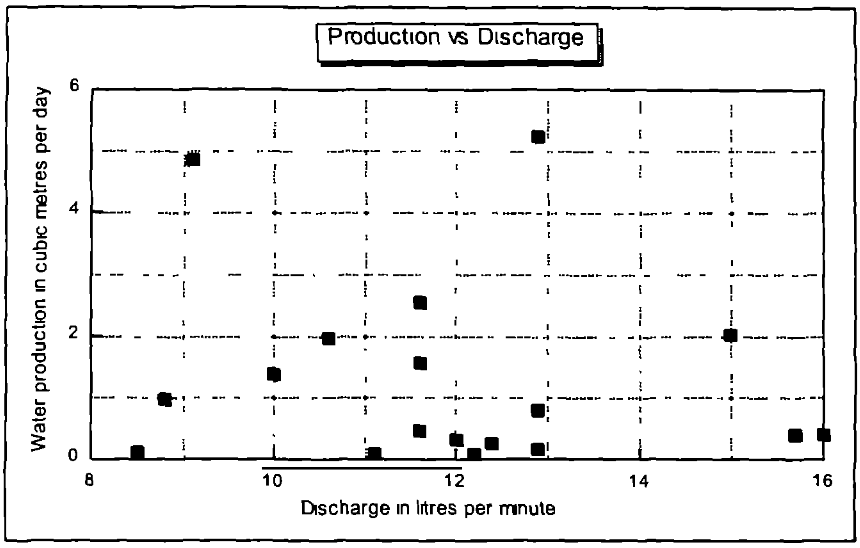


figure 6.1 pump production vs pump discharge

In the figure above, the points for HP3 and HP20 shows only one point as these values are very close to each other. Some relation between average production and average pump discharge can be noticed. Two out of eight pumps (about 25%) with a production of less than one cubic metres per day have a discharge less than 12 litres per minute. The handpumps which are hardly used are not considered in arriving at this relationship. That is in places where the production is less than one cubic metres per day, the discharge of the pump was found to be high, while in other places where the discharge was found to be less than 12 litres per minute. This was noticed in six out of such cases (about 75%). This appears to indicate a higher wear of the cup seals in pumps that are more heavily used.

6.1.2. Pump Leakage

A comparison between the average values of breakdown frequency, downtime and water production for the leaky and non-leaky handpumps is shown below.

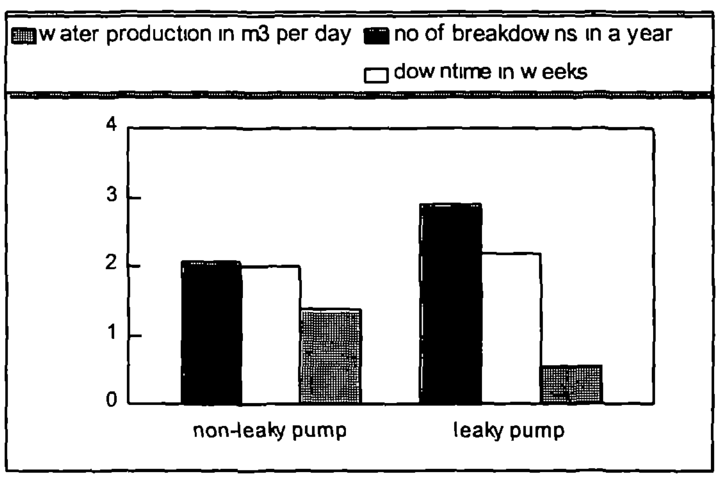


figure 6.2 comparison of production, breakdown and downtime of a non-leaky and leaky pump

From the above figure, it can be seen that the average number of breakdowns is more in a leaky pump. The leakage in these pumps might have been caused due to the frequent repair of pump parts resulting in damages to the pipe joints. The average volume of water collected from the five leaky pumps was less than 0.56 cubic metres per day.

Also a bar chart is drawn for the average value of discharge, number of users and consumption rate for a leaky and non-leaky pump.

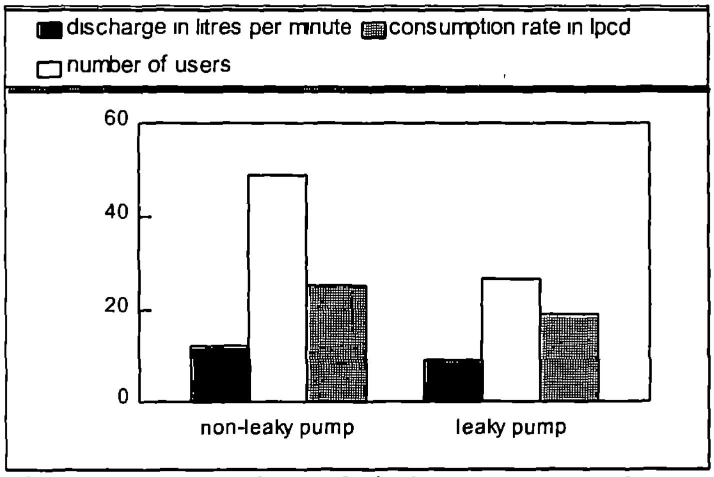


figure 6.3 comparison of discharge, consumption rate and number of users for a non-leaky and leaky pump

In places where the number of users are high, the pumps were found to be non-leaky. The reason for this, to me, seems that people may force the Panchayath authorities to get the pump repaired at the earliest. Majority of the non-leaky pumps are extensively used by the public where as four out of five leaky pumps have a low use. Also the per capita consumption rate of the users collecting water from a non-leaky handpump is found to be more.

6.1.3. Breakdown Frequency

The graph of breakdowns in a year versus the number of users is given below. From the figure below, it can be seen that the breakdown frequency of two per year is most, which is relatively high in caparison to the data in the literature. No clear correlation between number of users and breakdown frequency is found.

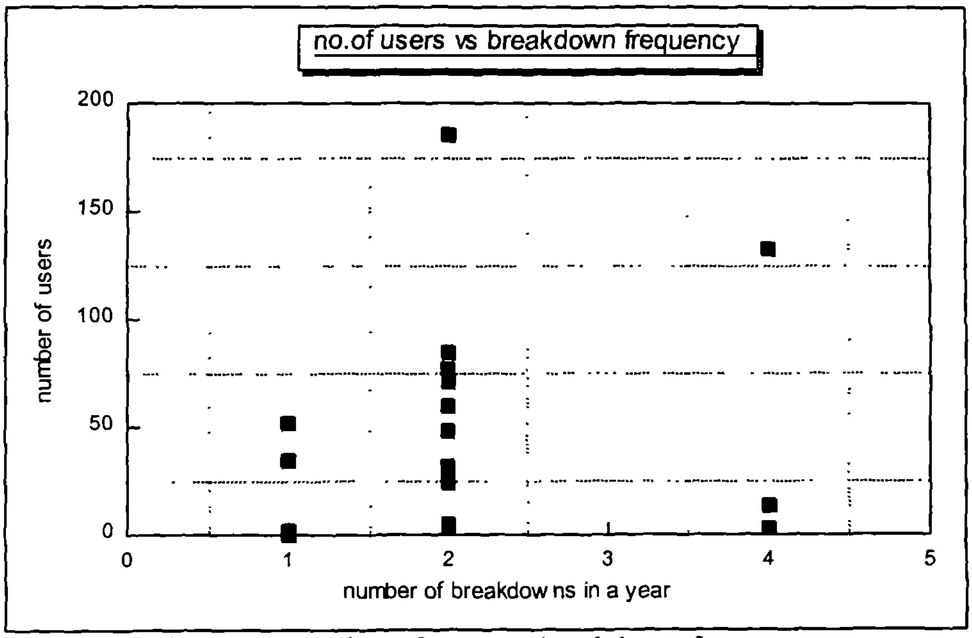


figure 6.4 number of users vs breakdown frequency

6.1.4. Downtime

The number of handpump users versus the average downtime in handpumps is drawn below.

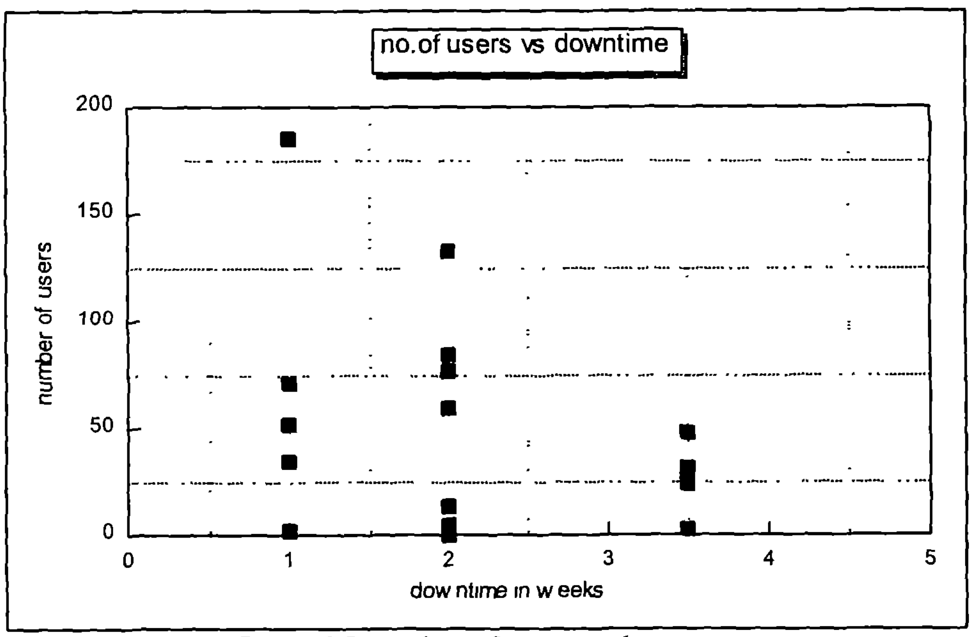


figure 6.5 number of users vs downtime

No definite relation has not been noticed with the downtime of handpumps with number of users although in 80% of the cases the downtime was found to be two weeks or less irrespective of the number of users. This may be the result of pressure by the users on repairs to the pumps.

6.1.5. Broken and Badly Constructed Platform

A comparison of the average no. of users and the poorly constructed platforms is given below. It can be noticed from the figure that the average number of users were more in case of broken and damaged platforms which is expected due to heavy usage of handpumps.

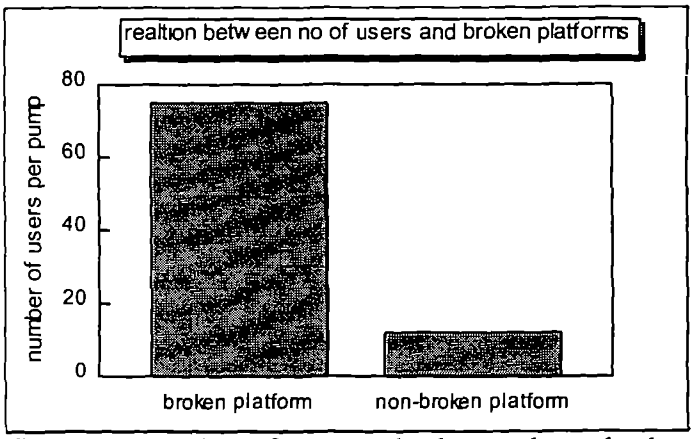


figure 6.6 number of users vs broken and non-broken platforms

The figure drawn for the pump condition versus number of users shows that the pump condition was the worst where the usage of handpump was more. This may be due to heavy usage.

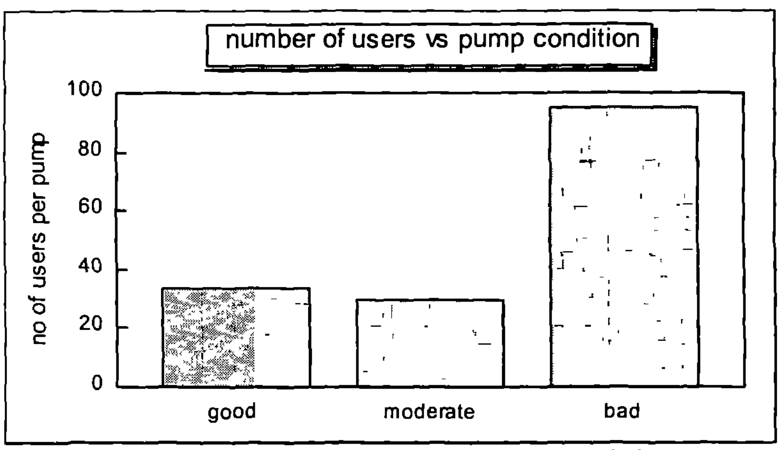


figure 6.7 number of users vs pump conditions

6.1.6. Pump Environment

The average number of users using a handpump with a stained platform is very less when compared with the handpump users in a non-stained platform. The following figure shows the relationship. The reason for this may be the poor water quality in handpump having stained platform. The stains is an indication of excess iron content in water.

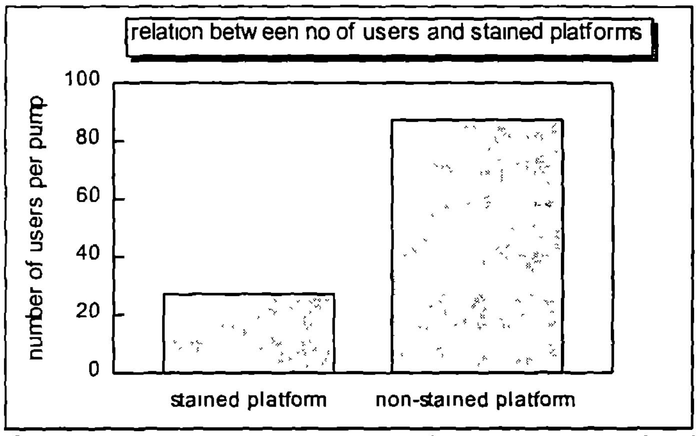


figure 6.8 number of users vs stained and non-stained platforms

6.2. Use of Handpumps

A total of twenty handpumps are covered in the present study. Nine out of twenty handpumps are not used for drinking and cooking. But out of these nine pumps, seven are partially used for washing and bathing and two pumps are not used at all.

6.2.1. Number of users per Handpump

The average number of handpump users in the study area is given in table 5.11. On an average 64 persons per pump (142% of the total average) are using the 11 handpumps in the study area during the wet season for drinking and cooking. This value may increase slightly in the summer as it can be seen from the table 5.16 and even the pump with most users does not exceed the limits specified by the national guidelines of 250 persons per handpump. Hence from the above mentioned average persons per pump, it can be seen that wherever the pump is heavily used, it is used for drinking and cooking.

6.2.2. Volume of Water Collected per Household

Since the handpumps which are used for drinking and cooking are extensively used, they are only considered in the following sections for comparing the indicators which affect the use of handpumps. In the study area, the average discharge of a handpump comes to 10.8 litres per minute and the average number of users per handpump comes to 64 for handpumps which are used for drinking and cooking. Hence the discharge of the pump is sufficient to meet the guideline value of 40 lpcd. But people collected only 24.3 lpcd on an average from these handpumps which shows the presence of other traditional sources or the consumption level is below the guideline value or people may be impatient in waiting near the handpumps as it can be seen from the table 5.13 that in some cases the waiting time near the handpump was more, about 15 to 30 minutes per each collection of a pot of water

6.2.3. Average Distance of Household from the Handpump

It can be noticed from the tables 5 14 and 5 15 that the average distance to the handpump in Kozhinjampara Panchayath is the lowest among the Pachayaths selected for the study and the consumption rate from handpumps in this Panchayath is the maximum This gives more strength to the relation that, the less is the distance to a water source, the more will be the amount of water collected The following graph obtained by drawing the average distance to the handpump and the consumption level provided by the system, shows that wherever the distance to the handpump was less, people collected more water This may be due to the fact that people find it difficult to carry water for a longer distance

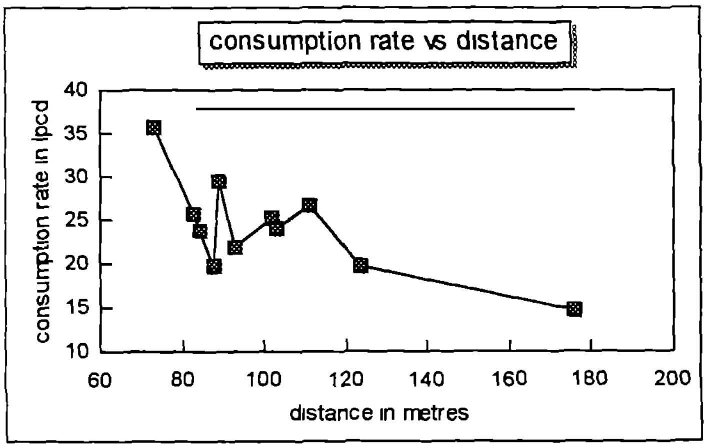


figure 6.9 consumption rate vs distance

6.2.4. The Presence of Alternate Sources

The presence of alternate water sources may have affected the water consumption rate from the handpump In the study area, ten handpumps had an iron content of more than 1 0 mg/lit. Hence in order to study the presence of alternate water sources, the distance to the handpumps having a total iron content of less than 1 0 mg/lit and the distance to the neighbouring traditional sources near these handpumps were considered The graph below indicates that the distance for handpump users is well below than for traditional sources

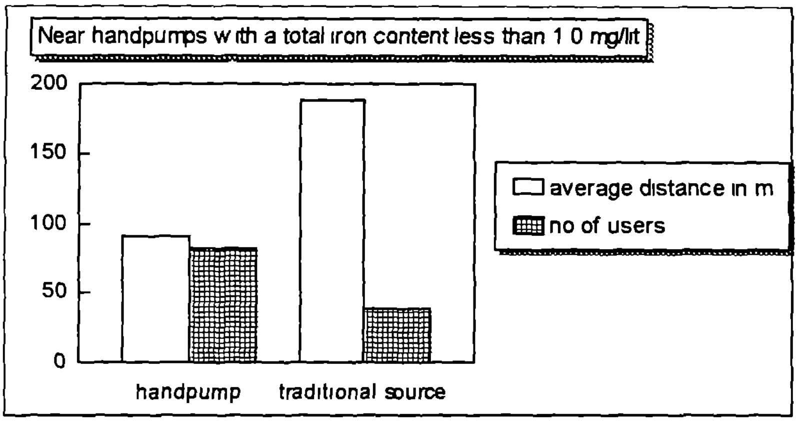


figure 6 10 comparison of handpump and traditional source when the iron content was less than 1 0 mg/lit

From the figure, it can be seen that when the distance to the handpump was less, people preferred handpump water over the traditional water where the iron content was low In all other cases, when the iron content was high, especially more than 1 0 mg/lit people preferred traditional sources irrespective of the distance Data on this are provided in appendix VII

6.2.5. Water Quality

Tests were carried out on 20 handpump water samples. A graph has been drawn with the concentrations of iron and the number of users per pump for 11 handpumps which are extensively used

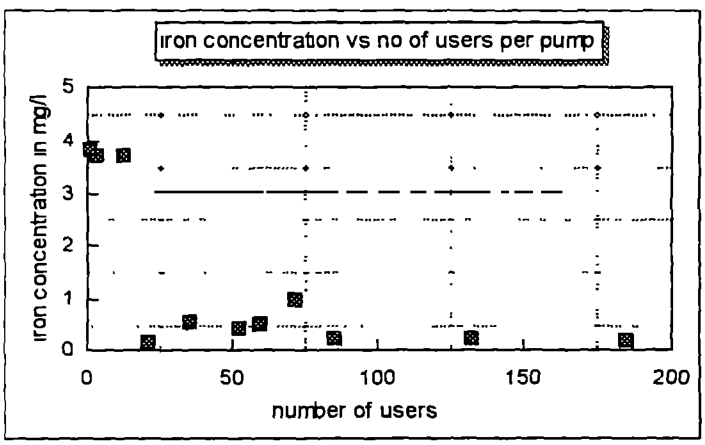


figure 6 11 iron concentration vs number of users

From the above figure, it can be seen that normally when the iron concentration increases, the user acceptability decreases During the field interviews, about 45% of the non-users (households) of handpumps complained about the taste difference of handpump water from the traditional sources for drinking and cooking which is due to the excess iron present in fourteen out of the twenty samples collected

There is no specific relationship is obtained between hardness and number of users although twelve out of twenty samples were found to have a hardness of less than 200 mg/lit of $CaCO_3$

The electrical conductivity(EC) of eight out of 11 extensively used water samples were found to be less than 800 μS/cm which is mineralised Ten out of 20 water samples were found to have an EC of more than 500 μS/cm implies that the handpump water is mineralised This may be due to either nitrates or chlorides

Only one out of 20 samples showed a pH value of less than 6.5 Twelve samples showed a pH value ranging between 6.5 and 7 0 and others were above 7 0 The corrosion of pump material, according to literature is high when pH is less than 6 5 Hence the corrosion of pump parts is appears to be less in this area, even though a slight rate of 0 2 mm/year is expected since thirteen out of 20 samples showed a pH of less than 7 0. The cause of iron may be the aquifer characteristics, for which detailed investigations have to be carried out

Heavy floc formation of handpump water was noticed over a day This may be due to the fact that the water when pumped out to the atmosphere comes in contact with the oxygen in the air and the dissolved iron oxidises to the stable ferric state, forming flocs of ferric hydroxide which can cause turbidity to the handpump water.

In general, the quality of handpump water affects the user acceptability of handpumps If the water quality is poor, especially with regard to iron people will reject the handpump This also explains the figure 6 11 Hence water quality of handpump water is one of the most important factors which affected the user acceptability of handpumps in the study area

Chapter 7

Conclusions and Recommendations

This chapter discusses the topic and objectives in the beginning. It then provides the general findings obtained in the present study in two sections, one under functioning of handpumps and second under use of handpumps. It then gives a few recommendations of the study to improve the functioning and use. Action plan to implement the recommendations is suggested in the last section.

7.1. Topic and objective of the study

Borewell with handpumps are one of the major sources of water in the rural areas of Palakkad district. About 2200 borewells with handpumps were installed in different Panchayaths of the district.

Problems were found to exist with respect to quality, quantity and user acceptance of handpump water supply in this area.

As an assistant engineer working for KWA in Palakkad, the author was engaged in the construction of handpumps. From the personal observations of the author, it has been found that frequent breakdowns were occurring to handpumps in this area. Complaints were also received from the public on bad taste of handpump water which appears to be the results of high iron content possibly due to the results of corrosion of the pump material.

Hence the present study investigates the problems encountered with the handpump schemes in the rural areas of Palakkad district. The objectives of the study are;

1. to evaluate the performance of handpumps with regard to functioning,
2. to evaluate the performance of handpumps with regard to water use,
3. to obtain an in-sight into the water quality of handpump water in Palakkad district, and
4. to suggest possibilities to improve the performance of handpumps in Palakkad.

7.2. Conclusions

The conclusions drawn from this study on functioning an use of handpump systems are given separately under this section.

7.2.1. Functioning of Handpumps

1. Nineteen out of twenty pumps were found to be functioning but only half of them met the discharge standards set by the Bureau of Indian Standards(BIS). The low discharge of the pumps may be due to the high wear of cup seals in pumps that are more heavily used. In

the eight places where the pump production was more than one cubic metres per day, 75% of the pumps were found working at a discharge which is lower than the standard value. In places where the pump production was less than one cubic metres per day, only 25% of the pumps were found working with a low discharge than the standards set by the BIS.

2. Twenty five percentage of the pumps had unacceptable levels of leakage which might have been caused due to the damages of pump joints because of frequent repairs. Four of these five pumps had a low use and average volume collected from leaky pumps is less than 0.56 cubic metres per day.

3. An average breakdown frequency of handpumps of once in six months was noticed which is relatively high in comparison to the data in the literature. This may be due to poor workmanship or due to poor quality of materials or both. In about 80% of the cases, the downtime was found to be two weeks or less even in the low use handpumps irrespective of the number of persons which may imply that there is some pressure by the public on Panchayath authorities to get the pump repaired quickly.

4. A considerable difference in the pump condition were noticed in the three selected Panchayaths, mainly due to the difference in use although maintenance may also play a role. The platform condition was bad in pumps that were heavily used. Community involvement in maintenance of handpumps seems to be low. Greasing of handpump chain is one of the simplest preventive maintenances to the India Mark II handpumps. Nineteen of the twenty visited handpumps were not greased which implies low community involvement in handpump maintenance .

7.2.2. Use of Handpumps

The following conclusions were obtained in the present study on use of handpumps.

1. Only eleven out of 20 handpumps were used for drinking and cooking in the study area and most of these pumps were heavily used. Another seven were used for cattle feeding and drinking, but not for drinking. The average number of users per pump for the most extensively used handpumps comes to 64 persons per pump for drinking and cooking, which is well below the national guidelines set up by the GOI of 250 users per pump.

2. The average volume of water collected by a household in the study area is 22.9 lpcd, below the national guideline of 40 lpcd. This means that the presence of other traditional sources for bathing and washing such as rivers, ponds and streams are near by. Also the traditional practices of bathing and washing were found as one of the main reasons for non-use of handpumps for the purposes of bathing and washing.

3. About 52% of the households use dugwell and 39% use handpump and 7.3% use piped water as their water source for drinking and cooking in the study area during dry season. In the wet season a few people turn to the traditional wells and handpump use is reduced

by a fraction.

4. About 71% of the non-users(households) of handpump complained about the taste difference of handpump water from the taste of traditional sources for drinking and cooking. About 17% of the non-users(households) complained that the distance to the handpump was the single largest reason for the non-use of handpump systems.

5. The average distance to the households in the three selected Panchayaths were found to be different. It was noticed that when the distance to the handpump was less, people preferred handpump water over the traditional sources where the iron content in the water sample was low.

6. The water quality of handpump water was found to be poor. Fourteen out of 20 water samples had above guideline value of 0.3 mg/l total iron content, although three out of this fourteen samples had an iron content nearly 0.45 mg/l, well below the maximum permissible value of 1.0 mg/l set by the BIS for drinking water. Sixteen out of 20 water samples had fluoride concentrations above the allowable limits of 1.0 mg/l set by the BIS for drinking water, eventhough only four samples out of these sixteen were found to have a fluoride concentration of more than 1.5 mg/l, guideline set by the WHO. Eight out of the 11 extensively used handpump water samples had an EC of 700 μS/cm or less. The total iron concentration of handpump water samples were found to be very high when compared to the dugwell water and heavy floc formation was observed when the handpump water was stored over a day.

7.3. Recommendations

The following recommendations are suggested for improving the functioning and use of handpump systems.

7.3.1. Functioning of Handpumps

1. Enhancing preventive maintenance, including repair of cupseals when pump discharge falls below a pre-determined minimum of 10 litres per minute at 40 strokes per minute. This 10 litres per minute is set because, even after finding the reduced discharge, it is assumed that the repair may take few more days and in any case the pump has to be repaired before the discharge goes below 9 litres per minute at 40 strokes per minute.

2. Make alterations in the existing handpumps to India Mark III to facilitate village level operation and maintenance(VLOM) to reduce the breakdowns and particularly downtime in the handpumps.

3. Give emphasis on community participation in construction and operation and maintenance of handpump facilities in the communities in which they use handpumps extensively.

4. An effective maintenance system involving the above said communities and the Panchayath authorities has to be set up as a first step to give training to the community members in operation and maintenance of handpumps to ensure quicker repairs.

7.3.2. Use of Handpumps

1. Modification in the design on India Mark II will enhance the volume of water produced which may improve the performance of handpumps in terms on functioning which will result in the improvement of the service level. Hence it is suggested to make the modifications.

2. Ground water quality investigations should become part and parcel of all handpump programmes. Before the implementation of a new handpump programme, the water quality in the nearby borewells may tested and if the quality is found good, then proceed with the programme otherwise try to give better service by improving the existing the water source.

3. Explore the possibility of surface water or traditional wells as an alternative water source of water supply where the handpump water quality is unacceptable.

7.4. Action Plan

An action plan is prepared to implement the recommendations suggested. The plan is proposed in such a way as to implement immediate measures, short term measures and long term measures.

7.4.1. Immediate Measure

This measures are proposed to implement within six months. It is proposed to create community awareness and training in operation and maintenance of handpumps in the extensively used handpump communities. Emphasis on introduction of pump performance inventory by caretakers to enhance preventive maintenance if the pump discharge drops below 10 litres per minute at 40 strokes per minute.

In Kerala, the proposals for the 10th Five Year Plan has been collected from the public, and preferences has been given to the public in the selection of developmental activities. Hence a sort of community participation has been already started in the state by the present Government. Public health and drinking water has been made as a part of this Five Year Plan Programme. It is proposed to implement awareness programme on handpump maintenance as a start. Once the community is aware of the repairs, then give training to the community members on handpump operation and maintenance. As this involves mainly the study materials, the money required for this programme may be less and it can be met from the Panchayath Fund.

7.4.2. Short Term Measure

This is proposed to complete within one to three years mainly focussing on functioning and well used handpumps. It is proposed to explore the possibilities to change to India Mark III, to facilitate the VLOM design after one year. This will be given a second priority since an awareness among the community members are required for the effective functioning of the system. This can be carried out by the Panchayath authorities. Budget allocation for this programme has to be obtained from the Government. Detailed survey has to be carried out in the beginning to find which community has to be served first. Then an year wise action plan has to worked out to cover the non-functioning and leaky pumps by giving a first preference to the population benefitted by each pump. Financial sanction and budget allocation has to be obtained before taking up a programme. Possibility of contribution from the community involved may also be explored.

It is proposed to carry out water quality testing on existing handpump water samples. Measures have to be taken to protect the traditional water sources such as dugwells in places where the handpump water quality is found poor. The water sample collection and testing can be entrusted to one of the reputed firms and the protection works to the dugwells can be arranged by the Grama Panchayaths.

7.4.3. Long Term Measure

This is proposed to implement after five years. It is proposed to conduct a detailed study on the aquifer characteristics before taking up a project. This has to be done by another Government agency such as State Groundwater Department. Hence the programme has to be worked out before starting an exploration programme. If the ground water quality is poor, explore the possibilities of alternative source for water supply, possibly river water.

APPENDIX I

OBSERVATION SHEET FOR FUNCTIONING AND WATER USE BY HANDPUMP SCHEMES

Block : Panchayath : Ward :
Location :
Date of visit : Time of arrival : am/pm

handpump

Condition of handpump :good/moderate/bad*
Condition of platform and drainage facilities: :good/moderate/bad**
No.of households within a radius of 250 meters. :
No.of users coming from longer distances :

Pump performance

out of service :yes/no
no.of strokes to fill a bucket of 15 L @ 50 str/min :
leakage :
General remarks :

*Condition of handpump:

Play of handle more than .3.mm	Yes/No
Clear signs of corrosion	Yes/No
Bolts loose	Yes/No
Lacks grease	Yes/No
Top Cover damaged	Yes/No
Damaged bearings	Yes/No
Leaking tank	Yes/No

**Condition of Platform and Drainage Facility

Stained Platform	Yes/No
Broken Platform	Yes/No
Broken Drain	Yes/No
Stagnant pools of water nearby	Yes/No

APPENDIX II

QUESTIONNAIRE PREPARED FOR FUNCTIONING AND USE OF HANDPUMP SCHEMES

Block : Panchayath : Ward :
Location :
Distance from pump : m Date of visit : Time of arrival : am/pm

Name : Profession :
No.of persons in household adults:
children:
Who normally fetches water in the family ? :
Do you use handpumps ? :
(why/why not) ? :
Do you like water from handpump ? :
(why/why not) ? :
Are there other sources ? In rainy season :
In dry season :
How many buckets do you collect per day ? :
Where do you wash clothes ? :
Where do you take bath ? :
What are the other sources of water ? :
Are you getting sufficient water from HP ? :
(why/why not) ? :
When do you collect water ?Which is the rush hour :
Is there any queue to collect water in the peak hour :
Do you have to wait for a long time in the queue ? :
How long ? :
Can water be pumped continuously :
If not, how long you have to wait to pump another bucket:

Does the pump breakdown - often(every month)/regularly(three months)/occasionally(6months)
What is the usual downtime :
Who is doing the maintenance work ? :
Are mechanics available locally ? :

APPENDIX III
SOURCE-USE MATRIX

Purpose	Source of water						Reasons for non-use of Handpumps											
	Handpump		Dugwell		*River/stream		taste		distance		colour		Not enough water		Traditional Practices		others	
	dry	wet	dry	wet	dry	wet	dry	wet	dry	wet	dry	wet	dry	wet	dry	wet	dry	wet
Drinking																		
Cooking																		
Washing																		
Bathing																		
Personal hygiene																		
Gardening																		
Cattle feeding																		

APPENDIX IV
EXISTING WATER RESOURCE INFORMATION

LOCATION OF COMMUNITY WELLS	PERENNIAL	SEASONAL
PONDS	PERENNIAL	SEASONAL
HANDPUMPS	WORKING	NOT WORKING
RIVERS AND STREAMS	PERENNIAL	SEASONAL

APPENDIX V

DETAILS OF LOCATIONS OF HANDPUMPS AND DUGWELLS AND THEIR CODES

Panchayath	Ward	Sl.No	Location	Source	Code
AGALI	X	1	Near Plamaram to the left side of Agali Road	Borewell	HP1
		2	Near Geetha Talkies second handpump towards Agali	Borewell	HP2
		3	Near Geetha Talkies first handpump towards Agali	Borewell	HP3
		4	Public Open Draw well near HP3	Dug well	DW1
		5	Private O.D well of Moitheen at Thavalam	Dug well	DW2
		6	Thavalam Centre	Borewell	HP4
	X I	7	In Adiyakkandiyoor Ooru	Borewell	HP5
		8	In Seenkara near St. George Convent & L.P. School	Borewell	HP6
		9	Near Chemmannur Anganwadi	Borewell	HP7
		10	In Chemmannur Ooru	Dug well	DW3
		11	Bhavani River water at Chemmannur	River	RW1
SREEKRISHNA-PURAM	V	12	Near Thalayanakkad School	Borewell	HP8
		13	Near Thannikkal Parambu	Borewell	HP9
		14	Private O.D. well of Achuthan Nair at Thannikkal Parambu	Dug well	DW4
		15	Private O.D. well of Kamalakshi - shares same strata of HP9	Dug well	DW5
		16	Punchappadam Sharathukunnu scheduled Cast colony	Borewell	HP10
		17	Public O.D. well in Punchappadam Sharathukunnu colony	Dug well	DW6
	V I	18	Near Pattathilppadi	Borewell	HP11
		19	Near Tharuvarappalliyal	Borewell	HP12
		20	Private O.D. well of Janaki at Tharuvarappalliyal	Dug well	DW7
		21	Near Mampallikkalampadi	Borewell	HP13
		22	Public O.D. well near Mampallikkalampadi School	Dug well	DW8
KOZHINJAM-PARA	III	23	Near Boyathara Mariyamman Covil	Borewell	HP14
		24	Near Boyathara Soudamman Covil	Borewell	HP15
		25	Near Government Veterinary Hospital	Borewell	HP16
		26	Private O.D. well of Narayan near paddy field	Dug well	DW9
	X	27	Near Nagaliyamman Covil Road	Borewell	HP17
		28	Near Kallupalam	Borewell	HP18
		29	Near rice mill	Borewell	HP19
		30	Near Perumparachalla Scheduled Cast colony	Borewell	HP20
		31	Private O.D. well of Govinda Swany near HP17	Dug well	DW10
		32	Public O.D. well near Perumparachalla S.C. colony	Dug well	DW11

APPENDIX VI

TABULATED OBSERVATION SHEET

Code	No of strokes @ 50 str/min	Discharge in lit /min @ 5 0 str/min	Discharge in lit /min @40 str/min	Leakage	Ave No of persons residing less than 250 m	% of number of average handpump users to the total number of persons using within a distance of 250 metres: for drinking and cooking	% of number of average handpump users to the total number of persons using within a distance of 250 metres: for washing and bathing	$ Condition of Handpump: PH	CC	BL	LG	CD	DB	LT	Rating G	Rating M	Rating B	# Condition of PF & DF: SP	BP	BD	SW	Rating G	Rating M	Rating B
HP1	62	14 5	11.6	-	104	100	72	-	-	-	+	-	-	-	*			+	-	-	+		*	
HP2	56	16.1	12 9	-	170	89	72	-	-	-	+	-	-	-	*			-	+	+	+			*
HP3	62	14.5	11 6	-	94	67	61	-	-	-	+	-	-	-	*			+	+	-	+			*
HP4	45	20.0	16.0	+	118	0	17	-	+	-	+	-	-	-		*		+	+	+	+			*
HP5	56	16 1	12 9	-	118	89	0	-	-	+	+	-	-	-	*			+	+	+	+			*
HP6	85	10.6	8 5	+	83	0	0	-	-	-	+	-	-	-	*			+	-	-	-	*		
HP7	56	16.1	12.9	-	118	0	0	-	-	-	-	-	-	-	*			+	-	-	-	*		
HP8	68	13 2	10 6	-	100	100	56	+	-	-	+	-	+	+			*	+	-	-	-	*		
HP9	58	15.5	12.4	-	60	0	11	-	-	-	+	-	-	+		*		+	-	-	-	*		
HP10	60	15.0	12 0	-	80	11	0	+	-	-	+	-	-	-		*		+	-	-	-	*		
HP11	65	13.8	11.1	-	40	11	0	-	-	-	+	-	-	-	*			+	-	-	+		*	
HP12	59	15.3	12.2	-	40	0	11	-	-	-	+	-	-	-	*			+	-	-	-	*		
HP13	46	19.6	15.7	-	60	0	78	-	-	-	+	-	-	-	*			+	-	-	-	*		
HP14	82	11.0	8.8	+	92	0	78	-	-	-	+	-	-	-	*			+	+	+	+			*
HP15	72	12.5	10.0	-	138	0	33	-	-	-	+	-	-	-	*			-	-	-	+	*		
HP16	62	14.5	11.6	+	92	89	33	+	-	-	+	-	-	-		*		-	-	-	+	*		
HP17	0	0 0	0 0	+	46	22	67	+	+	-	+	-	+	-			*	+	-	-	+		*	
HP18	79	11.4	9.1	-	200	100	89	+	-	-	+	+	+	-			*	-	+	+	+		*	
HP19	48	18 8	15 0	-	70	89	67	+	-	+	+	+	-	+			*	-	+	-	+			*
HP20	62	14.5	11.6	-	115	0	100	-	-	-	+	-	-	-		*		-	+	+	+			*

$ Condition of Handpump
PH - Play of the handle more than 3 mm
CC - Clear signs of corrosion
BL - Bolts loose
LG - Lacks grease
CD - Top cover damaged
DB - Damaged bearings
LT - Leaking water tank

Condition of Platform and Drainage facilities
SP - Stained Platform
BP - Broken Platform
BD - Broken Drain
SW - Stagnant pools of water near by

Codes used for filling the table
G - Good, M - Moderate and B - Bad
+ for YES and - for NO

APPENDIX VII

TABULATION OF FIELD INTERVIEWS

1. Codes used to fill up the Heading of the table

DHP - Approximate distance of handpump if any existing from the households in metres
DTS - Approximate distance of traditional source if any existing from the households in meters
TS - Trditional source of water
AW - Approximate amount of water consumed by each person in a household in litres per capita per day
D - Dry season of the year (Summer season)
W - Wet season of the year (Monsoon season)
Source - Source of water used for each purpose
Reason - Reasons for non-use of handpump water
PH - Peak Hour Response, BF - Breakdown frequency of handpump system, DT - Average downtime on handpumps, and DT- Waiting time near handpumps

2. Codes used to complete the table

a. For source of water
HP - Handpump
W1 - Public Dugwell
W2 - Private Dugwell
RW - River Water
PW - Pond Water
SW - Stream Water
PP - Piped Water

c. Traditional Sources
SW - Stream Water

b Reasons for non-use ofhandpump water
TD - Water tastes different from the traditional water source
DM - Distance more
CW - Coloured water
HW - Have own private dugwell
NE - Not enough water is available
WR - Traditional practice of washing clothes in river
WP - Traditional practice of washing clothes in pond
BR - Traditional practice of taking bath in river
BP - Traditional practice of taking bath in pond
NA - Not applicable

d. Breakdown frequency
1 for once in 1month
2 for once in 3 months
3 for once in 6 months
4 for once in more than 6 months

e. Average downtime on handpumps
a for less than one day, b for 1 - 3 days, c for 3 -5 days,
d for 5 - 10 days, e for 10 - 15 days, f for 15 -30 days
g for more than 30 days

f. Peak hour response
FN - Morning 6AM-8PM, AN-Evening 4PM-8PM

g.Waiting time near Handpump
p for less than 10 minutes, q for 10 - 15 minutes, r for 15-30 minutes and s for > 30 minutes

See also codes used in Appendix V for the corresponding traditional sources in each ward

Code	Sl. No	DHP	DTS	T S	A W	Drinking				Cooking				Washing				Bathing				Per hygiene				Gardening				Cattle feeding							
		in m	in m		in lpcd	Source		Reason		Source		Reason		Source		Reason		Source		Reason		Source		Reason		Source		Reason		Source		Reason		BF	DT	PH	WT
						D	W	D	W	D	W	D	W	D	W	D	W	D	W	D	W	D	W	D	W	D	W	D	W	D	W	D	W				
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)	(33)	(34)	(35)	(36)	(37)	(38)
	1	25	200	SW	50	HP	HP			HP	HP			RW	RW	WR	WR	HP	HP			HP	HP			HP	HP			HP	HP			3	e	FN	q
	2	60	250	SW	20	HP	HP			HP	HP			RW	RW	WR	WR	HP	HP			HP	HP			HP	HP			HP	HP			3	e	AN	q
	3	90	300	SW	17	HP	HP			HP	HP			RW	RW	WR	WR	HP	HP			HP	HP			HP	HP			HP	HP			3	e	AN	q
	4	150	380	SW	30	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			2	e	FN	q
HP1	5	280	20	SW	8	HP	HP			HP	HP			W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2			3	e	FN	q
	6	180	400	RW1	45	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			3	d	FN	q
	7	75	300	RW1	20	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			NA	NA			3	e	FN	q
	8	20	150	RW1	20	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			NA	NA			3	d	FN	q
	9	40	200	RW1	20	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			NA	NA			3	e	FN	q
	1	180	50	W2	50	HP	W2		HW	HP	W2		HW	HP	W2		HW	HP	W2		HW	HP	W2		HW	HP	W2		HW	HP	W2		HW	2	d	FN	r
	2	120	500	RW1	50	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			2	d	FN	s
	3	90	500	RW1	30	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			3	d	FN	r
	4	70	500	RW1	30	HP	HP			HP	HP			HP	HP			RW	RW	BR	BR	HP	HP			HP	HP			NA	NA			3	d	FN	r
HP2	5	30	500	RW1	33	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			2	e	FN	r
	6	20	500	RW1	29	HP	HP			HP	HP			HP	HP			RW	RW	BR	BR	HP	HP			HP	HP			NA	NA			3	e	FN	r
	7	25	500	RW1	20	HP	HP			HP	HP			HP	HP			RW	RW	BR	BR	HP	HP			HP	HP			NA	NA			2	d	FN	r
	8	85	550	RW1	36	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			2	d	FN	r
	9	200	15	DW1	30	W1	W1	TD	TD	W1	W1	TD	TD	W1	W1	DM	DM	W1	W1	DM	DM	W1	W1	DM	DM	W1	W1	DM	DM	W1	W1	DM	DM				
	1	170	450	RW1	30	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			3	d	FN	r
	2	120	450	RW1	25	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			NA	NA			3	d	FN	r
	3	80	10	W2	30	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW				
	4	60	400	RW1	24	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			3	d	FN	r
HP3	5	15	400	RW1	25	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			NA	NA			3	d	FN	r
	6	20	400	RW1	25	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			NA	NA			3	d	FN	q
	7	25	15	DW1	30	W1	W1	TD	TD	W1	W1	TD	TD	W1	W1	DM	DM	W1	W1	DM	DM	W1	W1	DM	DM	W1	W1	DM	DM	W1	W1	DM	DM				
	8	70	400	RW1	12	HP	HP			HP	HP			RW	RW	WR	WR	RW	RW	BR	BR	HP	HP			HP	HP			NA	NA			3	d	FN	q
	9	190	10	W2	13	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW				

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24	(25)	(26)	(27	(28)	(29)	(30)	(31)	(32	(33)	(34)	(35)	(36)	(37)	(38)
	1	200	10	W2	14	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW				
	2	180	10	W2	20	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW				
	3	100	5	DW2	13	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW				
	4	70	150	DW2	10	W2	W2	TD	TD	W2	W2	TD	TD	RW	RW	WR	WR	RW	RW	BW	BW	HP	HP			HP	HP			NA	NA			2	d	AN	p
HP4	5	20	20	W2	20	W2	W2	TD	TD	W2	W2	TD	TD	W2	W2	HW	HW	W2	W2	HW	HW	HP	HP			HP	HP			NA	NA			2	e	AN	p
	6	15	100	DW2	17	W2	W2	TD	TD	W2	W2	TD	TD	W2	W2	CW	CW	HP	HP			HP	HP			HP	HP			NA	NA			2	d	FN	p
	7	35	100	DW2	20	W2	W2	TD	TD	W2	W2	TD	TD	HP	HP			HP	HP			HP	HP			HP	HP			NA	NA			2	d	FN	p
	8	90	10	W2	21	W2	W2	TD	TD	W2	W2	TD	TD	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW				
	9	80	100	DW2	14	W2	W2	TD	TD	W2	W2	TD	TD	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW				
	1	250	50	SW	10	SW	SW	DM	DM	SW	SW	DM	DM	RW	RW	WR	WR	RW	RW	BR	BR	SW	SW	DM	DM	SW	SW	DM	DM	NA	NA						
	2	110	100	SW	38	HP	HP			HP	HP			RW	RW	WR	WR	RW	RW	BR	BR	HP	HP			HP	HP			NA	NA			4	a	FN	q
	3	10	300	RW1	15	HP	HP			HP	HP			RW	RW	WR	WR	RW	RW	BR	BR	HP	HP			HP	HP			HP	HP			4	a	FN	r
	4	150	300	RW1	13	HP	HP			HP	HP			RW	RW	WR	WR	RW	RW	BR	BR	HP	HP			HP	HP			NA	NA			4	a	FN	q
HP5	5	175	300	RW1	21	HP	HP			HP	HP			RW	RW	WR	WR	RW	RW	BR	BR	HP	HP			HP	HP			HP	HP			4	a	FN	q
	6	12	300	RW1	15	HP	HP			HP	HP			RW	RW	WR	WR	RW	RW	BR	BR	HP	HP			HP	HP			NA	NA			4	a	FN	r
	7	20	300	RW1	10	HP	HP			HP	HP			RW	RW	WR	WR	RW	RW	BR	BR	HP	HP			HP	HP			NA	NA			4	a	FN	q
	8	70	300	RW1	13	HP	HP			HP	HP			RW	RW	WR	WR	RW	RW	BR	BR	HP	HP			HP	HP			NA	NA			4	a	AN	q
	9	85	300	RW1	12	HP	HP			HP	HP			RW	RW	WR	WR	RW	RW	BR	BR	HP	HP			HP	HP			NA	NA			4	a	FN	r
	1	30	10	W2	15	W2	W2	TD	TD	W2	W2	TD	TD	W2	W2	HW	HW	HP	W2		DM	HP	W2		HW	W2	W2	HW	HW	NA	NA			4	e	FN	p
	2	100	10	W2	10	W2	W2	TD	TD	W2	W2	TD	TD	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW				
	3	150	10	W2	11	W2	W2	DM	DM	W2	W2	DM	DM	W2	W2	DM	DM	RW	RW	BR	BR	W2	W2	DM	DM	W2	W2	DM	DM	W2	W2	HW	HW				
	4	250	10	W2	18	W2	W2	DM	DM	W2	W2	DM	DM	W2	W2	DM	DM	RW	RW	BR	BR	W2	W2	DM	DM	W2	W2	DM	DM	W2	W2	DM	DM				
HP6	5	220	30	RW1	10	RW	RW	DM	DM	RW	RW	DM	DM	RW	RW	DM	DM	RW	RW	DM	DM	RW	RW	DM	DM	W2	W2	DM	DM	NA	NA						
	6	230	25	RW1	12	RW	RW	DM	DM	RW	RW	DM	DM	RW	RW	DM	DM	RW	RW	DM	DM	RW	RW	DM	DM	W2	W2	DM	DM	NA	NA						
	7	250	20	RW1	17	RW	RW	DM	DM	RW	RW	DM	DM	RW	RW	DM	DM	RW	RW	DM	DM	RW	RW	DM	DM	W2	W2	DM	DM	NA	NA						
	1	10	25	DW3	18	W1	W1	CW	CW	W1	W1	CW	CW	W1	W1	CW	CW	W1	W1	CW	CW	W1	W1	CW	CW	HP	HP			NA	NA			4	e	FN	p
	2	15	30	DW3	10	W1	W1	CW	CW	W1	W1	CW	CW	W1	W1	CW	CW	W1	W1	CW	CW	W1	W1	CW	CW	HP	HP			NA	NA			4	e	FN	p
	3	200	20	W2	8	W2	W2	CW	CW	W2	W2	CW	CW	RW	RW	CW	CW	RW	RW	BR	BR	W2	W2	CW	CW	W2	W2	DM	DM	NA	NA						
	4	250	20	W2	10	W2	W2	CW	CW	W2	W2	CW	CW	RW	RW	CW	CW	RW	RW	BR	BR	W2	W2	CW	CW	W2	W2	DM	DM	NA	NA						
HP7	5	255	20	W2	10	W2	W2	CW	CW	W2	W2	CW	CW	RW	RW	CW	CW	RW	RW	BR	BR	W2	W2	CW	CW	W2	W2	DM	DM	NA	NA						
	6	80	10	DW3	10	W1	W1	TD	TD	W1	W1	CW	CW	W1	W1	DM	DM	RW	RW	BR	BR	W1	W1	DM	DM	W1	W1	DM	DM	W1	W1	DM	DM				
	7	85	10	DW3	10	W1	W1	TD	TD	W1	W1	CW	CW	W1	W1	DM	DM	RW	RW	BR	BR	W1	W1	DM	DM	W1	W1	DM	DM	W1	W1	DM	DM				
	8	85	25	DW3	10	W1	W1	TD	TD	W1	W1	CW	CW	RW	RW	WR	WR	RW	RW	BR	BR	W1	W1	DM	DM	W1	W1	DM	DM	W1	W1	DM	DM				
	9	240	50	W2	10	W2	W2	DM	DM	W2	W2	DM	DM	RW	RW	WR	WR	RW	RW	BR	BR	W2	W2	DM	DM	W2	W2	DM	DM	NA	NA						

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24	(25)	(26)	(27	(28)	(29)	(30)	(31)	(32	(33)	(34)	(35)	(36)	(37)	(38)
	1	100	150	W2	30	HP	HP			HP	HP			PW	PW	WP	WP	PW	PW	BP	BP	HP	HP			HP	HP			HP	HP			3	b	FN	p
	2	80	200	W2	17	HP	HP			HP	HP			PW	PW	WP	WP	PW	PW	BP	BP	HP	HP			HP	HP			HP	HP			3	b	FN	p
	3	40	200	W2	20	HP	HP			HP	HP			PW	PW	WP	WP	PW	PW	BP	BP	HP	HP			HP	HP			HP	HP			3	c	FN	q
	4	180	250	W2	25	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			3	b	FN	q
HP8	5	10	100	W2	25	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			3	b	FN	p
	6	140	200	W2	33	HP	HP			HP	HP			PW	PW	WP	WP	PW	PW	BP	BP	HP	HP			HP	HP			HP	HP			3	b	FN	p
	7	170	200	W2	30	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			3	b	FN	p
	8	110	300	W2	20	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			NA	NA			3	b	FN	q
	9	200	300	W2	20	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			NA	NA			3	b	FN	p
	1	10	5	W2	25	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW				
	2	25	5	DW4	20	W2	W2	TD	TD	W2	W2	TD	TD	HP	HP			W2	W2	HW	HW	W2	W2	HW	HW	HP	HP			W2	W2	HW	HW	3	d	FN	p
	3	80	70	DW4	23	W2	W2	TD	TD	W2	W2	TD	TD	HP	HP			W2	W2	HW	HW	W2	W2	DM	DM	HP	HP			W2	W2	DM	DM	3	d	FN	p
	4	90	70	DW4	17	W2	W2	TD	TD	W2	W2	TD	TD	PW	PW	WP	WP	PW	PW	BP	BP	W2	W2	DM	DM	HP	HP			NA	NA			3	d	FN	p
HP9	5	120	20	W2	17	W2	W2	TD	TD	W2	W2	TD	TD	PW	PW	WP	WP	PW	PW	BP	BP	W2	W2	DM	DM	HP	HP			NA	NA			3	d	FN	p
	6	150	50	W2	30	W2	W2	TD	TD	W2	W2	TD	TD	PW	PW	WP	WP	PW	PW	BP	BP	W2	W2	DM	DM	W2	W2			W2	W2	DM	DM				
	7	200	100	W2	25	W2	W2	TD	TD	W2	W2	TD	TD	PW	PW	WP	WP	PW	PW	BP	BP	W2	W2	DM	DM	W2	W2			W2	W2	DM	DM				
	8	220	5	DW5	20	W2	W2	TD	TD	W2	W2	TD	TD	PW	PW	WP	WP	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2			W2	W2	HW	HW				
	9	240	5	W2	21	W2	W2	TD	TD	W2	W2	TD	TD	PW	PW	WP	WP	PW	PW	BP	BP	W2	W2	DM	DM	W2	W2			W2	W2	DM	DM				
	1	70	50	W2	30	W2	W2	TD	TD	W2	W2	TD	TD	PW	PW	WP	WP	PW	PW	BP	BP	W2	W2	NE	NE	HP	HP			W2	W2	NE	NE	2	f	FN	s
	2	75	50	DW6	16	W1	W1	TD	TD	W1	W1	TD	TD	PW	PW	NE	NE	PW	PW	NE	NE	W1	W1	NE	NE	HP	HP			W1	W1	NE	NE	2	f	FN	r
	3	150	120	DW6	19	W1	W1	TD	TD	W1	W1	TD	TD	PW	PW	NE	NE	PW	PW	NE	NE	W1	W1	NE	NE	HP	HP			W1	W1	NE	NE	2	e	FN	r
	4	110	80	DW6	25	W1	W1	TD	TD	W1	W1	NE	NE	PW	PW	NE	NE	PW	PW	NE	NE	W1	W1	NE	NE	HP	HP			W1	W1	NE	NE	2	f	AN	s
HP10	5	180	100	DW6	17	W1	W1	TD	TD	W1	W1	NE	NE	PW	PW	NE	NE	PW	PW	NE	NE	W1	W1	NE	NE	HP	HP			W1	W1	NE	NE	2	f	AN	s
	6	120	10	W2	20	W2	W2	TD	TD	W2	W2	NE	NE	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW				
	7	150	40	DW6	17	HP	W1		TD	HP	W1		NE	PW	PW	NE	NE	PW	PW	NE	NE	W1	W1	NE	NE	HP	HP			W1	W1	NE	NE	2	f	FN	s
	8	180	10	DW6	15	W1	W1	TD	TD	W1	W1	NE	NE	PW	PW	NE	NE	PW	PW	NE	NE	W1	W1	NE	NE	HP	HP			W1	W1	NE	NE	2	f	FN	s
	9	200	20	DW6	17	W1	W1	TD	TD	W1	W1	DM	DM	PW	PW	NE	NE	PW	PW	NE	NE	W1	W1	NE	NE	W1	W1	DM	DM	W1	W1	NE	NE				
	1	50	10	W2	20	W2	W2	TD	TD	W2	W2	TD	TD	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW				
	2	60	5	W2	29	W2	W2	TD	TD	W2	W2	TD	TD	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW				
	3	150	5	W2	17	W2	W2	TD	TD	W2	W2	TD	TD	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW				
	4	180	25	W2	18	HP	W2		DM	HP	W2		DM	W2	W2	DM	DM	W2	W2	DM	DM	W2	W2	DM	DM	W2	W2	DM	DM	NA	NA			4	a	FN	p
HP11	5	200	10	W2	15	W2	W2	TD	TD	W2	W2	TD	TD	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	NA	NA						
	6	150	10	W2	21	W2	W2	TD	TD	W2	W2	TD	TD	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW				
	7	130	5	W2	20	W2	W2	TD	TD	W2	W2	TD	TD	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW				
	8	200	10	W2	18	W2	W2	TD	TD	W2	W2	TD	TD	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW				
	9	225	10	W2	15	W2	W2	TD	TD	W2	W2	TD	TD	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	NA	NA						

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24	(25)	(26)	(27	(28)	(29)	(30)	(31)	(32	(33)	(34)	(35)	(36)	(37)	(38)
	1	100	10	W2	30	W2	W2	TD	TD	W2	W2	TD	TD	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW				
	2	70	5	W2	30	W2	W2	TD	TD	W2	W2	TD	TD	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW				
	3	180	10	W2	30	W2	W2	TD	TD	W2	W2	TD	TD	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW				
	4	200	10	W2	20	W2	W2	DM	DM	W2	W2	DM	DM	W2	W2	DM	DM	W2	W2	DM	DM	W2	W2	DM	DM	W2	W2	DM	DM	W2	W2	DM	DM				
HP12	5	225	10	W2	15	W2	W2	DM	DM	W2	W2	TD	TD	W2	W2	DM	DM	W2	W2	DM	DM	W2	W2	DM	DM	W2	W2	DM	DM	NA	NA						
	6	70	10	DW7	25	W2	W2	TD	TD	W2	W2	TD	TD	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW				
	7	100	50	DW7	25	W2	W2	TD	TD	W2	W2	TD	TD	HP	HP			HP	HP			W2	W2	DM	DM	W2	W2	DM	DM	NA	NA			3	f	FN	p
	8	150	10	W2	17	W2	W2	TD	TD	W2	W2	TD	TD	W2	W2	DM	DM	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	NA	NA						
	9	130	10	W2	17	W2	W2	TD	TD	W2	W2	TD	TD	W2	W2	DM	DM	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	NA	NA						
	1	10	150	W2	14	W2	W2	TD	TD	W2	W2	TD	TD	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			3	f	FN	p
	2	45	120	W2	15	W2	W2	TD	TD	W2	W2	TD	TD	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			3	f	FN	p
	3	80	100	W2	12	W2	W2	TD	TD	W2	W2	TD	TD	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			3	f	FN	p
	4	130	10	W2	18	W2	W2	TD	TD	W2	W2	TD	TD	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW				
HP13	5	120	100	W2	17	W2	W2	TD	TD	W2	W2	TD	TD	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			3	f	FN	p
	6	170	100	W2	16	W2	W2	TD	TD	W2	W2	TD	TD	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			3	e	FN	p
	7	230	150	W2	20	W2	W2	TD	TD	W2	W2	TD	TD	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			3	f	FN	p
	8	200	10	W2	21	W2	W2	TD	TD	W2	W2	TD	TD	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW				
	9	250	120	W2	17	W2	W2	TD	TD	W2	W2	TD	TD	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			3	f	FN	p
	1	15	10	W2	75	PP	PP	TD	TD	PP	PP	TD	TD	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW				
	2	10	100	W2	50	PP	PP	TD	TD	PP	PP	TD	TD	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			3	f	FN	q
	3	40	100	W2	13	PP	PP	TD	TD	PP	PP	TD	TD	HP	HP			HP	HP			HP	HP			HP	HP			NA	NA			3	f	FN	q
	4	70	70	W2	20	PP	PP	TD	TD	PP	PP	TD	TD	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			3	f	FN	q
HP14	5	90	70	W2	17	PP	PP	TD	TD	PP	PP	TD	TD	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			3	f	FN	q
	6	75	70	W2	25	PP	PP	TD	TD	PP	PP	TD	TD	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			3	f	FN	q
	7	120	70	W2	20	PP	PP	TD	TD	PP	PP	TD	TD	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			3	f	FN	q
	8	140	100	W2	20	PP	PP	TD	TD	PP	PP	TD	TD	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			3	f	FN	q
	9	200	150	W2	25	PP	PP	DM	DM	PP	PP	DM	DM	PP	PP	DM	DM	PP	PP	DM	DM	PP	PP	DM	DM	PP	PP	DM	DM	NA	NA			3	f	FN	q
	1	5	200	DW9	20	PP	W2	DM	TD	PP	W2	DM	TD	PP	PP	CW	CW	HP	HP			HP	HP			HP	HP			HP	HP			3	e	FN	q
	2	20	170	DW9	20	PP	W2	DM	TD	PP	W2	DM	TD	PP	PP	CW	CW	HP	HP			HP	HP			HP	HP			HP	HP			3	e	FN	q
	3	45	200	DW9	25	PP	W2	DM	TD	PP	W2	DM	TD	PP	PP	CW	CW	HP	HP			HP	HP			HP	HP			HP	HP			3	f	FN	q
	4	60	20	DW9	21	PP	W2	TD	TD	PP	W2	TD	TD	PP	PP	CW	CW	HP	HP			HP	HP			HP	HP			HP	HP			3	f	FN	q
HP15	5	70	50	W2	25	W2	W2	TD	TD	W2	W2	TD	TD	HP	HP			HP	HP			W2	W2	HW	HW	HP	HP			HP	HP			3	f	FN	q
	6	90	10	W2	21	W2	W2	DM	DM	W2	W2	DM	DM	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	NA	NA						
	7	150	10	W2	17	W2	W2	DM	DM	W2	W2	DM	DM	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	NA	NA						
	8	200	10	W2	17	W2	W2	DM	DM	W2	W2	DM	DM	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	NA	NA						
	9	200	5	W2	25	W2	W2	DM	DM	W2	W2	DM	DM	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	NA	NA						

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24	(25)	(26)	(27	(28)	(29)	(30)	(31)	(32	(33)	(34)	(35)	(36)	(37)	(38)
	1	15	10	W2	15	HP	HP			HP	HP			W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	NA	NA			2	f	FN	q
	2	45	15	W2	21	HP	HP			HP	HP			W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	3	f	FN	q
	3	30	70	W2	25	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			3	f	FN	q
	4	60	50	W2	20	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			3	f	FN	q
HP16	5	80	100	W2	20	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			3	e	FN	q
	6	90	20	W2	20	HP	HP			HP	HP			W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	NA	NA			3	f	FN	q
	7	120	40	W2	17	HP	W2		TD	HP	W2		TD	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	NA	NA			3	f	FN	q
	8	150	30	W2	23	HP	W2		TD	HP	W2		TD	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	NA	NA			3	g	FN	q
	9	200	10	W2	20	W2	W2	DM	DM	W2	W2	DM	DM	W2	W2	DM	DM	W2	W2	DM	DM	W2	W2	DM	DM	W2	W2	DM	DM	W2	W2	DM	DM				
	1	5	10	W2	16	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			NA	NA			3	f	FN	s
	2	20	5	DW10	16	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			3	f	FN	s
	3	60	50	W2	16	W2	W2	NE	NE	W2	W2	NE	NE	W2	W2	NE	NE	W2	W2	NE	NE	W2	W2	NE	NE	W2	W2	NE	NE	NA	NA						
	4	50	30	W2	20	W2	W2	TD	TD	W2	W2	TD	TD	W2	W2	NE	NE	W2	W2	NE	NE	W2	W2	NE	NE	W2	W2	NE	NE	NA	NA						
HP17	5	70	30	W2	17	W2	W2	NE	NE	W2	W2	NE	NE	W2	W2	NE	NE	W2	W2	NE	NE	W2	W2	NE	NE	W2	W2	NE	NE	NA	NA						
	6	90	200	DW11	25	W2	W2	TD	TD	W2	W2	TD	TD	HP	HP			HP	HP			HP	HP			HP	HP			NA	NA			3	f	FN	r
	7	110	150	DW11	25	W2	W2	TD	TD	W2	W2	TD	TD	HP	HP			HP	HP			HP	HP			HP	HP			NA	NA			3	f	AN	r
	8	150	140	DW11	14	W2	W2	TD	TD	W2	W2	TD	TD	HP	HP			HP	HP			HP	HP			HP	HP			NA	NA			3	f	FN	r
	9	200	100	DW11	20	W2	W2	TD	TD	W2	W2	TD	TD	HP	HP			HP	HP			HP	HP			HP	HP			NA	NA			3	f	FN	r
	1	10	250	W1	30	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			3	a	AN	s
	2	50	200	W1	30	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			3	a	AN	s
	3	60	10	W2	25	HP	HP			HP	HP			W2	W2	DM	DM	HP	HP			HP	HP			HP	HP			HP	HP			3	a	FN	s
	4	80	250	W1	25	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			3	a	FN	r
HP18	5	120	170	W1	25	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			3	a	FN	r
	6	140	200	W1	20	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			3	a	AN	s
	7	150	50	W2	38	HP	HP			HP	HP			W2	W2	DM	DM	HP	HP			HP	HP			W2	W2	DM	DM	W2	W2	DM	DM	3	a	FN	s
	8	200	200	W1	33	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			3	a	FN	s
	9	190	200	W1	17	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			3	a	FN	s
	1	10	20	W1	25	HP	HP			HP	HP			HP	W1		NE	HP	W1		NE	HP	W1		NE	HP	W1		NE	HP	HP			4	a	FN	q
	2	15	25	W1	14	HP	HP			HP	HP			HP	W1		NE	HP	W1		NE	HP	W1		NE	HP	W1		NE	NA	NA			4	a	FN	q
	3	10	5	W2	25	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW				
	4	60	80	W1	38	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			4	a	FN	q
HP19	5	75	95	W1	30	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			4	a	FN	q
	6	100	150	W1	38	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			4	a	FN	q
	7	110	150	W1	100	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			4	a	FN	q
	8	130	10	W2	25	HP	HP			HP	HP			W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	4	a	FN	q
	9	150	180	W1	20	HP	HP			HP	HP			W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	W2	W2	HW	HW	4	a	FN	q

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24	(25)	(26)	(27	(28)	(29)	(30)	(31)	(32	(33)	(34)	(35)	(36)	(37)	(38)
	1	30	150	DW11	25	W1	W1	TD	TD	W1	W1	TD	TD	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			3	e	FN	q
	2	20	140	DW11	17	W1	W1	TD	TD	W1	W1	TD	TD	HP	HP			HP	HP			HP	HP			HP	HP			NA	NA			3	e	FN	q
	3	20	130	DW11	25	W1	W1	TD	TD	W1	W1	TD	TD	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			3	f	FN	q
	4	80	110	DW11	25	W1	W1	TD	TD	W1	W1	TD	TD	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			3	f	FN	q
HP20	5	90	120	DW11	30	W1	W1	TD	TD	W1	W1	TD	TD	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			3	e	FN	q
	6	95	130	DW11	33	W1	W1	TD	TD	W1	W1	TD	TD	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			3	e	FN	q
	7	120	180	DW11	36	W1	W1	TD	TD	W1	W1	TD	TD	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			3	e	FN	q
	8	200	110	DW11	50	W1	W1	TD	TD	W1	W1	TD	TD	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			3	e	FN	q
	9	150	100	DW11	28	W1	W1	TD	TD	W1	W1	TD	TD	HP	HP			HP	HP			HP	HP			HP	HP			HP	HP			3	e	FN	q

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