CONJUNCTIVE MANAGEMENT
NORTH BIHAR, INDIA

K. V. Raju
and
Jeffrey D. Brewer

APRIL 2000

IWMI INTERNATIONAL WATER MANAGEMENT INSTITUTE

ACIAR
Australian Centre for International Agricultural Research
TABLE OF CONTENTS

LIST OF TABLES........................................................................................................................................v

LIST OF FIGURES ........................................................................................................................................vii

FOREWORD ................................................................................................................................................ix

1. INTRODUCTION ....................................................................................................................................1
   1.1. OBJECTIVE OF THE STUDY .............................................................................................................1
   1.2. METHODOLOGY OF THE STUDY ....................................................................................................1
   1.3. ORGANIZATION OF THE REPORT ................................................................................................1

2. FEATURES OF THE STUDY AREA ....................................................................................................3
   2.1. NORTH BIHAR ..................................................................................................................................3
       2.1.1. Geographic Features of North Bihar ............................................................................................3
       2.1.2. Social and Demographic Features of North Bihar .....................................................................5
       2.1.3. Landholdings and Land Tenure in North Bihar ..........................................................................6
   2.2. THE EASTERN GANDAK AND VAISHALI BRANCH CANAL COMMANDS ................................6
       2.2.1. Major Features of the Canal System ............................................................................................6
       2.2.2. Water Availability in the VBC Command ...................................................................................8
           2.2.2.1. Climate and Rainfall ..............................................................................................................8
           2.2.2.2. The Gandak River ..................................................................................................................8
           2.2.2.3. Ground Water .......................................................................................................................9
   2.3. IRRIGATED AGRICULTURE IN NORTH BIHAR ........................................................................11
       2.3.1. Farming Seasons ........................................................................................................................11
       2.3.2. Principal Crops ..........................................................................................................................11
       2.3.3. Water Application to Crops .......................................................................................................12

3. MANAGING THE CANAL SYSTEM FOR THE VBC COMMAND ..................................................15
   3.1. CANAL TECHNOLOGY ..................................................................................................................15
   3.2. INSTITUTIONS FOR CANAL MANAGEMENT ............................................................................16
       3.2.1. Policies, Laws, and Regulations ..................................................................................................16
           3.2.1.1. Bihar Irrigation Laws and Written Policies ...........................................................................16
           3.2.1.2. Actual Irrigation Management Policies .............................................................................17
       3.2.2. Water Resources Department (WRD) .........................................................................................18
           3.2.2.1. WRD Organization for the Eastern Gandak Command .......................................................18
           3.2.2.2. WRD Management Organization for the VBC .................................................................19
           3.2.2.3. Operational Problems of the WRD Field Staff ..................................................................20
       3.2.3. Gandak Command Area Development Authority .................................................................20
       3.2.4. Local Institutions and Customs ...............................................................................................20
   3.3. CANAL MANAGEMENT METHODS .............................................................................................20
       3.3.1. Water Allocation .......................................................................................................................20
       3.3.2. Operation of the Headworks and the Main Canal ....................................................................21
       3.3.3. Operation of the Vaishali Branch Canal ..................................................................................22
       3.3.4. Water Distribution below the Outlets .......................................................................................22
   3.4. CANAL WATER DISTRIBUTION PERFORMANCE ..................................................................23
       3.4.1. Water Deliveries to the Vaishali Branch Canal .......................................................................23
       3.4.2. Performance of the Vaishali Branch Canal ..............................................................................24
4. MANAGING GROUND WATER USE IN THE VBC COMMAND

4.1. Technology for Ground Water Use

4.1.1. Types and Distribution of Wells in the VBC Command

4.1.2. Characteristics of Shallow Tubewells in the VBC Command

4.1.3. Characteristics of Deep Tubewells in the VBC Command

4.1.4. Pumpsets

4.1.5. Tubewell Installation

4.1.5.1. Location of Wells

4.1.5.2. Drilling Methods

4.1.5.3. Installation History

4.1.5.4. Costs of Installation

4.1.6. Tubewell Performance

4.1.7. Conditions of the Wells and Pumpsets

4.1.8. Tubewell Water Distribution Facilities

4.1.9. Tubewell Operation and Maintenance Costs

4.2. Institutions for Managing Ground Water Use

4.2.1. Policies, Laws, and Regulations

4.2.2. Local Institutions and Customs

4.2.3. Central Ground Water Board and Authority

4.2.4. Minor Irrigation Department

4.2.4.1. Tubewell Wing

4.2.4.2. Ground Water Directorate

4.2.5. Tubewell Subsidy Program

4.2.6. Group Tubewells: VASFA and Similar Organizations

4.2.6.1. Group Tubewells

4.2.6.2. VASFA

4.2.6.3. VASFA Tubewell Groups

4.2.6.4. VASFA Investigators

4.2.6.5. Local Group Tubewells

4.2.7. The Water Market

4.2.7.1. Basic Nature of the Water Market

4.2.7.2. Sellers and Buyers

4.2.7.3. Cartel Prices

4.2.7.4. Transacting Sales

4.2.8. Private Service Organizations

4.3. Methods for Managing Ground Water Use

4.3.1. Management of Private Tubewells

4.3.2. Management of Group Tubewells

4.3.2.1. VASFA Group Tubewells

4.3.2.2. The Sample Local Group Tubewell

5. Conjunctive Management in the VBC Command

5.1. Sources of Irrigation Water

5.1.1. Sources of Water in Kharif

5.1.1.1. Chakwa Minor

5.1.1.2. Madan Chapra Minor

5.1.1.3. Shampur Minor

5.1.1.4. Observations on Kharif Sources of Water

5.1.2. Sources of Water in Rabi

5.1.2.1. Chakwa Minor

5.1.2.2. Madan Chapra Minor
5.1.2.3. Shampur Minor

5.1.2.4. Observations on Rabi Sources of Water

5.2. LOW USE OF GROUND WATER

5.2.1. Ground Water and Kharif Paddy Cultivation

5.2.2. Ground Water and Rabi Wheat Cultivation

5.2.2.1. A Madan Chapra Minor Farmer

5.2.2.2. A Shampur Minor Farmer

5.2.3. Irrigated Agricultural Strategies in the VBC Command

5.3. INSTALLING A PRIVATE TUBEWELL

6. PERFORMANCE OF CONJUNCTIVE MANAGEMENT IN THE VBC COMMAND

6.1. WATER DISTRIBUTION PERFORMANCE

6.2. AGRICULTURAL PRODUCTION PERFORMANCE

6.3. ENVIRONMENTAL MANAGEMENT

7. OPPORTUNITIES TO IMPROVE THE RESULTS OF CONJUNCTIVE MANAGEMENT

7.1. CONJUNCTIVE MANAGEMENT AT GOVERNMENT LEVEL

7.2. CONJUNCTIVE MANAGEMENT TO REDUCE THE WATER LOGGING

7.3. CONJUNCTIVE MANAGEMENT FOR POVERTY ALLEVIATION

8. REFERENCES
# List of Tables

Table 1. Selected Demographic Features of Bihar and the Study Districts, 1991 .................. 5
Table 2. Average Rainfall in the Vaishali Branch Canal Area (mm) ........................................ 8
Table 3. 75% Dependable Flow in the Gandak River at Valmikinagar ................................. 9
Table 4. Water Table Depths in the Vaishali Branch Canal Area (meters) ....................... 10
Table 5. Groundwater Development in Bihar and the Study Districts, 1991 (million cubic meters) .................................................................................................................. 11
Table 6. Cropping Intensities in the Eastern Gandak Command ........................................... 12
Table 7. Details of Three Sample Minor Canals (1992) ......................................................... 16
Table 8. Indents and Amounts Supplied at Head of Vaishali Branch, Kharif 1992 (acre-feet) . 23
Table 9. Planned Annual Irrigation from the Vaishali Branch Canal ................................. 25
Table 10. Target and Achievement Area in Vaishali Branch Canal (ha) ............................. 27
Table 11. Wells in the Study Blocks, 1991 ............................................................................. 29
Table 12. Shallow Tubewell Characteristics in the Sample Minor ...................................... 31
Table 13. Installation History of Tubewells in the Study Area (to 1992) ......................... 33
Table 14. Average Operation and Maintenance Costs of Private Tubewells .................. 36
Table 15. Centrally Sponsored Subsidy Schemes for Groundwater Development, 1987-92 .... 39
Table 16. Subsidies for Tubewells through the Block Development Office (1992) ........... 40
Table 17. Private Tubewell Water Sellers and Buyers (1992-93) ......................................... 46
Table 18. Comparison of Sample Buyers and Sellers by Source, 1992-93 .......................... 46
Table 19. Chakwa Minor Sources of Water for Kharif 1991 ................................................ 52
Table 20. Madan Chandra Minor Sources of Water for Kharif 1991 ................................. 53
Table 21. Shampur Minor Sources of Water for Kharif 1991 ............................................. 53
Table 22. Chakwa Minor Sources of Water for Rabi 1991/92 ............................................. 55
Table 23. Madan Chandra Minor Sources of Water for Rabi 1991/92 ............................... 55
Table 24. Shampur Minor Sources of Water for Rabi 1991/92 .......................................... 56
LIST OF FIGURES

Figure 1. The Eastern Gandak Command Bihar.................................................................4
Figure 2. The Vishali Branch Canal Command.................................................................7
Figure 3. Indent and actual discharge at Vishali Branch Canal Head, August 1992...........25
Figure 4. Deliveries to Vishali Branch Canal, Kharif 1998.............................................26
FOREWORD

Socioeconomic development and poverty alleviation in many developing countries depend on water. Governments and Development Agencies recognized this issue and, invested heavily on water resources development projects during the Twentieth Century. Presently, opportunities for further water resources development are limited, either due to the absence of water or due to lack of financial resources. The demand for food is continuously increasing due to a steady rise in population. Irrigated agriculture, which consumes 69% of all freshwater resources, and produces 40% of all food, will require additional 17% water to meet the demand for food. This water is not available from primary sources (rain, snow melt, groundwater). Further, freshwater consumption in irrigated agriculture decreased to meet increasing demand of freshwater for domestic and industrial requirements. Therefore, water from all primary as well as secondary sources (drainage, sewage) will be used conjunctively in agriculture. The conjunctive water use has its implications as evaporation and transpiration of water will concentrate salts and pollutants and threaten environmental sustainability of agricultural lands. Proper institutional and technical strategies must be in place to manage water conjunctively to minimize threat to the environment. This study aims to address this concern.

The broad goals of the study are to, 'Identify combinations of institutions and technical strategies to manage surface and groundwater at regional scale, to promote environmental sustainability and to maximize agricultural productivity of water ('crop per drop'), initially in the Rechna Doab in Pakistan and Murrumbidgee Region in Australia'. This report reviews conjunctive water management issues in the North Bihar, India.

The study is being carried out by IWMI in collaboration with Pakistan Council of Research Water Resources (PCRWR), and CSIRO Land and Water, Griffith, NSW, Australia. The study is financially is sponsored by the Australian Council of International Agriculture Research, Australia.

S. A. Prathapar, Ph.D. MIE, Aust.
Director, Pakistan Program
1. INTRODUCTION

1.1. OBJECTIVE OF THE STUDY

The present report is a short study of conjunctive use of surface and ground water within the Vaishali Branch Canal Command of the Eastern Gandak Irrigation System, North Bihar, India. This report was prepared as one of four short studies under the Conjunctive Management Project being carried out by the International Water Management Institute in collaboration with CSIRO in Australia, and PCRWR in Pakistan and funded by the Australian Council for International Agricultural Research.

The overall goal of the project is define technologies, institutions, and management methods for the conjunctive management of multiple water sources - particularly surface water and ground water - that can lead to sustainable improvements in irrigated agricultural production while preventing or ameliorating environmental problems.

This study delineates technologies, institutions, and management methods in use in the selected Indian site and evaluates their effectiveness in promoting irrigated agricultural production and in preventing detrimental environmental effects such as waterlogging, salinization, etc.

1.2. METHODOLOGY OF THE STUDY

The present study is based largely on a study carried out by the authors in 1992-93 (Raju et al. 1994) in the same area. During that study, we collected additional documentary evidence and interviewed (in some cases re-interviewed) government officials and farmers in the area. In the first study, samples of farmers were studied in three subcommand areas over a period of a year, primarily through participant observation. Some technical studies were also carried out. In addition, various government officials were interviewed and documents collected.

The findings of the earlier study were updated by a short restudy in May 1999. For the restudy, groups of farmers were interviewed in different portions of the scheme. Also relevant government officials were interviewed both in field sites and in Patna, the capital of Bihar. Where available, appropriate records were obtained.

1.3. ORGANIZATION OF THE REPORT

The present report is organized as follows:

- Section 2 describes the study site, and outlines farming in the area.
- Section 3 describes the technologies, institutions, and management methods used to exploit the surface water.
- Section 4 describes the technologies, institutions, and methods used to exploit the ground water.
- Section 5 describes the conjunctive management of these sources.
- Section 6 evaluates the performance of conjunctive water management in terms of water distribution, agricultural production, and protection of the environment (environmental sustainability).
- Section 7 identifies the opportunities to improve the results of conjunctive management.
2. FEATURES OF THE STUDY AREA

2.1. NORTH BIHAR

The state of Bihar (Figure 1) is the ninth largest in size in India. The total area of the state is 173,877 square kilometers and its 1996 population was estimated at 93 million (Tata Services, 1998).

The state includes alluvial plains of the Gangetic basin in the north and Kaimur-Chotanagpur-Santhal plateau in the south. The alluvial plains are divided into two by the Ganges River flowing from west to east. The state, therefore, is conventionally divided into three ecological regions:

- North Bihar, including all the areas north of the Ganges River to the border of India with Nepal.
- Central Bihar, including the areas south of the Ganges River to the hills of the plateau region.
- South Bihar, including the plateau region covering the southern half of the state.

The study area lies in North Bihar.

2.1.1. Geographic Features of North Bihar

North Bihar is part of the vast alluvial Gangetic Plains. The North Bihar plain was built by the rivers - principally the Gogra, Gandak, Bagmati, Kamala and Kosi - that emerge from the Himalayas and flow to the Ganga and thence to the Bay of Bengal. Land in North Bihar has been created by the deposition over thousands of years of the heavy silt and detritus load brought by the rivers. This process has left very deep and potentially very productive alluvial soils in the area. The whole of North Bihar is composed of young and recent alluvium soil.

In building the land, the rivers have shifted channels many times. For example, it is likely that the Burhi Gandak River was once the bed of the Gandak River, but the latter moved westwards. This movement of rivers has left depressed areas, known locally as maun or chaur areas that are flooded seasonally by the rains.

The Vaishali Branch Canal (VBC) is part of the Eastern Gandak Command which is located in the western portion of North Bihar (Figure 1). The VBC is located in Muzaffarpur and Vaishali Districts. The Gandak Command is flat except for the hilly tracts of West Champaran District. In the districts of Muzaffarpur, Vaishali, and Samastipur the slope varies from 1 in 5000 to 1 in 20,000.
2.1.2. Social and Demographic Features of North Bihar

Table 1 shows selected demographic features of the state of Bihar and of the Muzaffarpur and Vaishali Districts taken from the 1991 census. These figures give some idea of the problems faced by the people in Bihar and in the study area. They show:

- The population density in the study area is very high and almost double the statewide population density. This is a general characteristic of North Bihar.
- Agriculture is the main occupation in the area. In Bihar as a whole, about 38% of the working population cultivate land and another 26% are primarily dependent on agricultural labor. A total of about 64% of the population are dependent on agriculture.
- The literacy rate is low reflecting low levels of social services and social development in the area.
- State per capita income is very low; the lowest in India. The all-India average is Rs 588.4 per month while, as shown, Bihar’s is only Rs 304.1 per month. Per capita income in North Bihar is well below the state average and is estimated at only about half of the national average (Prasad, 1993).
- Well over half the people in the state as a whole are below the Indian national poverty line; the percentage is even higher in North Bihar.

Table 1. Selected Demographic Features of Bihar and the Study Districts, 1991.

<table>
<thead>
<tr>
<th></th>
<th>Muzaffarpur District</th>
<th>Vaishali District</th>
<th>Bihar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total population</td>
<td>2,946,000</td>
<td>2,144,000</td>
<td>86,338,000</td>
</tr>
<tr>
<td>Population density</td>
<td>928 /sq km</td>
<td>1053 /sq km</td>
<td>497 /sq km</td>
</tr>
<tr>
<td>Working in agriculture</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td></td>
<td></td>
<td>60.7 %</td>
</tr>
<tr>
<td>Female</td>
<td></td>
<td></td>
<td>79.1 %</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>64.8 %</td>
</tr>
<tr>
<td>Literacy Rate</td>
<td></td>
<td></td>
<td>38.5 %</td>
</tr>
<tr>
<td>Per capita SDP*</td>
<td></td>
<td></td>
<td>Rs 304.1</td>
</tr>
<tr>
<td>Pop. below poverty line</td>
<td></td>
<td></td>
<td>55 %</td>
</tr>
</tbody>
</table>


During the study, we found that seasonal migration in search of employment, mainly to Punjab, Assam and metropolitan cities like Delhi and Calcutta, is common.

The population in the area is overwhelmingly Hindu and consists of a variety of castes, including Harijans. Multiple castes are found in all villages in the area. Caste membership remains very important for social relations in the area.
2.1.3. Landholdings and Land Tenure in North Bihar

Because of the high population density, the average operational farm holding is small. About three-fourth of the operational holdings are marginal (less than one hectare) in which the average size is merely 0.31 hectare (Sharma, 1998).

Farmland in the area is privately owned and the owners farm a significant portion. Sharecropping is common. The standard sharecropping arrangement is that the landlord provides the land while the sharecropper provides all other inputs. At the end of the season, the sharecropper gives half the harvest to the landlord.

We found a high proportion of sharecroppers in the area but were unable to get exact figures. The present Bihar Tenancy Act gives long term sharecroppers and leaseholders very strong rights. Hence landowners are unwilling to give land on long term arrangements. At the same time, the state government is not capable of protecting individuals from physical violence instigated by powerful persons and groups. In this situation, many sharecroppers prefer to make private and secret arrangements that give them stability. Thus, farmers show considerable reluctance to admit to being a sharecropper. Knowledgeable persons in the villages estimate that 60-75% of the farmers are sharecroppers.

Land fragmentation is a widespread phenomenon. For example, one farmer in 1992-93 sample owned 0.90 acre divided into four fields located in two different places. Another sample farmer owned 6 acres has divided into 29 fields in eight different locations. This fragmentation decreases farming efficiency and increases costs.

2.2. THE EASTERN GANDAK AND VAISHALI BRANCH CANAL COMMANDS

2.2.1. Major Features of the Canal System

The Gandak River flows down from the Himalayas in Nepal and joins the Ganges at Patna, the capital of Bihar. A diversion weir located at the junction of the borders of Nepal, Uttar Pradesh, and Bihar diverts water into several main canals, of which the biggest are the Western Gandak and Eastern Gandak Main Canals. About three kilometers from the river, the Eastern Gandak Main Canal splits into three; the largest branch - called the Tirhut Main Canal (TMC) - continues about southeast into Bihar. Construction of the Eastern Gandak System began in 1961 and was stopped, before completion, in 1985. Figure 1 shows the Eastern Gandak Command area.

The TMC was planned to be 275 kilometers long; however only about 240 kilometers were constructed. The distribution system below the main canal was completed only as far as the Vaishali Branch Canal offtake at about 169 kilometers from the TMC head, although some work has been done below that point. The total planned command area for the Tirhut Main Canal is over 600,000 hectares. Overall, about 70% has been completed.

The Vaishali Branch Canal is located in the tail portion of the TMC as constructed. Baya River and Bhushali Distributary Canal bound the VBC command area (Figure 2) on the west and Jaitpur Branch Canal on the east. The VBC command lies in Vaishali and Muzaffarpur Districts. Further details of the VBC system are given below.
Figure 2. The Vishali Branch Canal Command.

Some of the discussion below is taken from our detailed studies carried out in 1992-93 in three minor canals. These included Chakwa Minor in the head reach of the VBC, Madan Chapra Minor
off of the Bishunpur Sub-Distributary in the middle reaches of the VBC and Shampur Minor in the tail reach of the VBC.

2.2.2. Water Availability in the VBC Command

2.2.2.1. Climate and Rainfall

North Bihar lies in the monsoon subtropical zone. It is characterized by a wet monsoon season from June through September, followed by cooler and drier weather from October through February, and then followed by a hot summer season with occasional thundershowers and dust storms from March to the middle of June. Normal annual rainfall in the Bihar portion of the Gangetic Plains is 1092 mm.

Temperatures vary from highs of 41°C in May or early June to lows of around freezing in January. The Gandak Command area is one of the humid areas of the state. Humidity is lowest (52%) in the months of March and April and highest (83%) during the rainy months of July and September.

Table 2 shows the average rainfall in the area. This table shows a markedly skewed seasonal pattern; over 85% of the annual rainfall fall from June through September. However, rainfall can vary markedly from year to year and from location to location.

2.2.2.2. The Gandak River

The Bihar State Second Irrigation Commission divided the state into 21 river basins. Of these 21 basins, seven are in North Bihar, six in Central Bihar and seven in South Bihar. The Ganga stem is treated as a separate basin. According to the Second Irrigation Commission, 75% dependable surface water availability from different river basins has been worked out be 339,675.80 MCM, of which 59% is from river basins in the North Bihar.

Table 2. Average Rainfall in the Vaishali Branch Canal Area (mm).

<table>
<thead>
<tr>
<th>Month</th>
<th>Muzaffarpur District</th>
<th>Vaishali District</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>13.8</td>
<td>12.2</td>
</tr>
<tr>
<td>February</td>
<td>19.7</td>
<td>18.3</td>
</tr>
<tr>
<td>March</td>
<td>7.0</td>
<td>9.5</td>
</tr>
<tr>
<td>April</td>
<td>15.8</td>
<td>7.7</td>
</tr>
<tr>
<td>May</td>
<td>47.8</td>
<td>28.4</td>
</tr>
<tr>
<td>June</td>
<td>172.7</td>
<td>152.1</td>
</tr>
<tr>
<td>July</td>
<td>301.1</td>
<td>256.5</td>
</tr>
<tr>
<td>August</td>
<td>297.0</td>
<td>294.5</td>
</tr>
<tr>
<td>September</td>
<td>241.2</td>
<td>294.0</td>
</tr>
<tr>
<td>October</td>
<td>57.5</td>
<td>47.7</td>
</tr>
<tr>
<td>November</td>
<td>5.1</td>
<td>7.8</td>
</tr>
<tr>
<td>December</td>
<td>2.6</td>
<td>3.6</td>
</tr>
<tr>
<td>Total rainfall</td>
<td>1181.3</td>
<td>1132.3</td>
</tr>
<tr>
<td>June-Sept rainfall</td>
<td>1012.0</td>
<td>997.1</td>
</tr>
</tbody>
</table>

Source: CWRS 1993
Data on the availability of water in the Gandak River barrage at Valmikinagar is given in Table 3. This data clearly shows the large variation in flow between the rainy and dry seasons. The capacity of the Eastern Main Canal is 443.4 cusecs and that of the Western Main Canal is 367.9 cusecs. The total is 811.3 cusecs. Table 3 shows that the combined capacity of these two canals is exceeded, with 75% dependability, from June through November every year.

Canal water needed to meet crop requirements was assessed in 1982/83. Findings revealed that if crop water requirements as per specifications in the original design are to be fully met, then the Tirhut Main Canal would probably suffer water shortages between February and March every year assuming that all irrigation needs are met from the canal system. At the present level of development of the system, the river flow is adequate to serve the whole system (CWRS, 1993).

Table 3. 75% Dependable Flow in the Gandak River at Valmikinagar.

<table>
<thead>
<tr>
<th>Month</th>
<th>Flow (cusecs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>June</td>
<td>1324.60</td>
</tr>
<tr>
<td>July</td>
<td>4568.62</td>
</tr>
<tr>
<td>August</td>
<td>4622.00</td>
</tr>
<tr>
<td>September</td>
<td>4005.39</td>
</tr>
<tr>
<td>October</td>
<td>1911.53</td>
</tr>
<tr>
<td>November</td>
<td>966.89</td>
</tr>
<tr>
<td>December</td>
<td>575.64</td>
</tr>
<tr>
<td>January</td>
<td>372.83</td>
</tr>
<tr>
<td>February</td>
<td>311.74</td>
</tr>
<tr>
<td>March</td>
<td>293.74</td>
</tr>
<tr>
<td>April</td>
<td>294.74</td>
</tr>
<tr>
<td>May</td>
<td>546.06</td>
</tr>
</tbody>
</table>

Source: CWRS 1993

2.2.2.3. Ground Water

The Gangetic plains of Eastern India—including major portions of Eastern Uttar Pradesh, Bihar, and West Bengal—have a very large groundwater potential. Because of water from the Himalayan Rivers, together with annual rainfall ranging from 1,000 mm in the west to well over 3,000 mm in the east, there is a great deal of easily accessible groundwater in the area. Also, the agricultural potential of the region is very high since the region has deep and productive soils and a generally good climate. Because of the alluvial soils and abundant groundwater in the region, development of groundwater for irrigation is both cheaper and far faster than development of canal systems. The estimated groundwater availability in Bihar is 33,645.6 MCM, of which 48% is located in the North Bihar.

The Gangetic Plains are deep alluvial formations, which attain a thickness of approximately 2500 meters in parts of North Bihar. Most of the area is underlain by aquifers at varying depths. The soil consists of various grades of sand, silt clay and kankar. Clean sand beds that constitute between 40 and 80 percent of the soil strata form the aquifers.
### Table 4. Water Table Depths in the Vaishali Branch Canal Area (meters).

<table>
<thead>
<tr>
<th>Well</th>
<th>Year</th>
<th>Sahebganj Block</th>
<th>Paroo Block</th>
<th>Vaishali Block</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Pre-Post-Monsoon</td>
<td>Change</td>
<td>Pre-Post-Monsoon</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Change</td>
<td></td>
<td>Change</td>
</tr>
<tr>
<td>Surface Perco</td>
<td>1983</td>
<td>4.40 3.60</td>
<td>0.80   2.29 2.09</td>
<td>0.20 6.10 4.90</td>
</tr>
<tr>
<td>lation Well</td>
<td>1984</td>
<td>4.50 3.28</td>
<td>2.22   3.51 1.79</td>
<td>1.72 5.89 3.71</td>
</tr>
<tr>
<td></td>
<td>1985</td>
<td>4.49 2.06</td>
<td>2.43   3.73 1.57</td>
<td>2.16 3.97 2.09</td>
</tr>
<tr>
<td></td>
<td>1986</td>
<td>4.30 3.34</td>
<td>1.96   3.36 1.23</td>
<td>2.13 5.59 3.12</td>
</tr>
<tr>
<td></td>
<td>1987</td>
<td>4.44 2.75</td>
<td>1.89   3.94 2.08</td>
<td>1.86 5.84 3.00</td>
</tr>
<tr>
<td></td>
<td>1988</td>
<td>4.32 3.48</td>
<td>0.84   3.78 2.37</td>
<td>1.41 5.74 4.14</td>
</tr>
<tr>
<td></td>
<td>1989</td>
<td>4.17 3.10</td>
<td>1.07   3.70 1.91</td>
<td>1.79 5.82 3.72</td>
</tr>
<tr>
<td></td>
<td>1990</td>
<td>4.48 2.84</td>
<td>1.64   3.61 2.18</td>
<td>1.43 - 3.35 -</td>
</tr>
<tr>
<td></td>
<td>1991</td>
<td>4.50 3.25</td>
<td>1.25   3.65 2.40</td>
<td>1.35 5.78 3.70</td>
</tr>
</tbody>
</table>

| State Tube | 1983 | 4.05 3.27       | 0.78   2.01 1.55 | 1.37 5.01 4.90 | 1.25 |
| well       | 1984 | 5.39 2.83       | 2.56   4.38 0.97 | 3.41 4.41 2.53 | 1.91 |
|            | 1985 | 4.14 1.76       | 2.38   - 0.85 - | - - 0.60 - |
|            | 1986 | 3.84 2.07       | 1.77   4.23 0.42 | 3.81 3.99 1.93 | 2.06 |
|            | 1987 | 5.61 2.45       | 3.16   4.77 1.27 | 3.50 4.50 1.91 | 2.05 |
|            | 1988 | 4.26 4.14       | 0.12   4.65 2.66 | 1.99 4.46 2.95 | 1.51 |
|            | 1989 | 4.09 2.89       | 1.20   4.57 2.02 | 2.55 4.40 1.86 | 2.54 |
|            | 1990 | 4.02 2.65       | 1.37   2.39 2.10 | 0.69 - 1.49 - |

Source: State Groundwater Directorate, Minor Irrigation Department, Patna, 1992. Measurements of the groundwater table depth were from figures for the villages of Isachapra, Dharpari and Senbaruna in the Sahebganj, Paroo and Vaishali Blocks, respectively.

Subsurface water in North Bihar flows generally southeasterly towards the Ganges River, a pattern modified by the recharge and discharge patterns of the tributaries of the Ganges. In general, the hydraulic gradient is of the order of 1:5000. The quality of the ground water of the aquifer system is good. To a depth of about 100 meters, electrical conductivity ranges between 400 to 950 micromhos/cm indicating low salinity. The water is generally suitable for irrigation.

Mainly the monsoon rains recharge the aquifers. The Bihar State Groundwater Directorate measures the water table before and after the monsoon every year. As shown in Table 4 for Sahebganj, Paroo, and Vaishali Blocks in the VBC area, the water table drops as low as 6.10 meters below the ground surface before the monsoon and rises as high as 0.42 meters below the ground following the monsoon. The fluctuations of the water table over the year are generally in the range of one to three meters.

The relationship between groundwater recharge and usage in Bihar and the Muzaffarpur and Vaishali Districts in 1991 is shown in Table 5. This table suggests that only 36% and 52%
respectively of the groundwater resources of Muzaffarpur and Vaishali Districts have been
developed for irrigation. Others question these figures and suggest that they may be too high.
However, these figures should be viewed with caution, most professionals’ feel that these
calculations give only the order of magnitude of the potential groundwater resources.

Table 5. Groundwater Development in Bihar and the Study Districts, 1991 (million cubic meters)

<table>
<thead>
<tr>
<th></th>
<th>State of Bihar</th>
<th>Muzaffarpur District</th>
<th>Vaishali District</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Total replenishable groundwater</td>
<td>33,773</td>
<td>998</td>
<td>633</td>
</tr>
<tr>
<td>2. Utilizable for irrigation</td>
<td>28,706</td>
<td>849</td>
<td>530</td>
</tr>
<tr>
<td>3. Actual net draft</td>
<td>6,761</td>
<td>305</td>
<td>260</td>
</tr>
<tr>
<td>4. Balance</td>
<td>21,945</td>
<td>544</td>
<td>279</td>
</tr>
<tr>
<td>5. Level of development</td>
<td>24 %</td>
<td>36 %</td>
<td>48 %</td>
</tr>
</tbody>
</table>


The Bihar Second Irrigation Commission (GOB, 1994) estimated that the ultimate irrigation
potential from minor irrigation, including ground water irrigation, comes to 5.6 million ha. Out of
5.6, 3.63 million ha (2.98 million ha from groundwater and 0.65 million ha from surface water) of
irrigation potential has been envisaged through completed and ongoing projects. This potential has
been created through 600,000 private borings, about 1.2 million bamboo borings, nearly 90,000
dugwells, and 5,600 state tubewells of which most are in the non-functioning state.

2.3. IRRIGATED AGRICULTURE IN NORTH BIHAR

2.3.1. Farming Seasons

Three agricultural seasons are recognized in North Bihar. The agricultural year begins with the
kharif (rainy) season from mid-June through mid-November, followed by the rabi (cool) season
from mid-November through the end of February or mid-March, and the followed by the summer,
also called the hot season, from mid-March until the monsoon rains come in mid-June.

2.3.2. Principal Crops

The Eastern Gandak Command is primarily a kharif paddy growing area. Wheat is the principal
rabi crop, although significant areas are planted in other crops, including maize and barley.
Mustard is the major oilseed crop and sugarcane, jute, mesta and tobacco are other important cash
crops. A wide variety of other crops are also grown, including perennial crops. There has been
expansion of the area under perennial crops - mostly fruit trees - in recent years because of
difficulties in getting labor for seasonal crops. As mentioned earlier, many men migrate to work in
Punjab and other areas with higher wage rates. Much of the land is fallow in summer, but some
high value crops are grown.

derived from these calculations is reduced by 30 percent, to account for the uncontrollable drainage
flow and transpiration by deep rooted vegetation, to obtain "net recoverable recharge."
Table 6. Cropping Intensities in the Eastern Gandak Command.

<table>
<thead>
<tr>
<th>Location on the Tirhut Main Canal</th>
<th>Cropping Intensity in Command Area</th>
<th>Cropping Intensity outside the Command</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1966-67</td>
<td>1984-85</td>
</tr>
<tr>
<td>Head reach</td>
<td>161 %</td>
<td>163 %</td>
</tr>
<tr>
<td>Middle reach</td>
<td>160 %</td>
<td>172 %</td>
</tr>
<tr>
<td>Tail reach</td>
<td>150 %</td>
<td>155 %</td>
</tr>
</tbody>
</table>


Planners of the Gandak Canal System projected a cropping intensity of 180% within the command after completion of the project. As shown in Table 6, the cropping intensity in the tail reach of the Gandak Command in 1984-85 was only 5% more than the cropping intensity in 1966-67 before canal irrigation began and only a little more than the cropping intensity outside the command.

The most important cropping sequence is paddy in kharif followed by wheat in rabi followed by fallow during summer. The dominance of this crop sequence will be demonstrated later.

2.3.3. Water Application to Crops

Paddy and wheat are the dominant crops in the area. For that reason, irrigation for these two crops dominates considerations of irrigation.

For these crops, farmers in the area use the check basin method of water application. In this method the field is divided into smaller units so that each unit has a nearly level surface. Bunds and ridges are constructed around the area forming a basin within which the irrigation water is controlled. The supply channel is aligned on the upper side of the area and there is usually one lateral channel for every two rows of check basins. The basins are filled to the desired depth and the water is retained till it infiltrates into the soil.

The local agricultural university recommends irrigating paddy 20-25 times during the season and recommends irrigating wheat four times.

- For paddy, the total water requirement is 1200-1500 mm. Also, standing water is desired to keep weed growth down. However, the water needed to keep water in the fields may not be available. Because paddy is grown only during the rainy season, rains and the high water table can be depended upon to supply some portion of the water requirement. Thus farmers figure that, at a minimum, they have to provide four watering events to ensure a paddy crop. The timings are a) transplanting, b) flowering, c) grain filling, and d) before maturity.
- For wheat, the total water requirement is 240 mm. Farmers say that 3-4 irrigation events are ideal. However, for reasons of lack of water, farmers generally plan on giving water only two times during the season: a) at 21 days after seeding, and b) at around 50 days after seeding. Each time they give less than 50-100 mm and depend upon rainfall and the high ground water table to make up the difference. The first water is considered crucial, the second is less important.

Every crop has its own proper water requirement and irrigation pattern. Although farmers are aware of the differences among crops, when considering irrigation patterns over a season, they fall into describing four irrigation events of all crops other than perennial tree crops and grass. That is,
the four-irrigation events’ pattern for paddy and wheat serves the farmers as a conceptual model for crop irrigation.

The major exceptions are the perennial crops: fruit trees, timber trees, and grass. Grass is kept in a very few fields for forage and generally is not irrigated. Trees, however, are more valuable and sometimes are irrigated. However, many trees can tap the high water table directly making irrigation unnecessary even during the dry summer season.
3. MANAGING THE CANAL SYSTEM FOR THE VBC COMMAND

3.1. CANAL TECHNOLOGY

The Eastern Gandak System is, as already mentioned, a gravity canal system bed by a diversion from the Gandak River at the border of India with Nepal. The Tirhut Main Canal (TMC) starts about 3 kilometers from the headworks and runs about 240 kilometers to the southeast. The Vaishali Branch Canal (VBC) offtake is located about 158 kilometers from the head of the TMC. This is in the tail reach of the Eastern Gandak System.

From its headgate, the VBC runs for about 47 kilometers, beyond which it is called the Bhagwanpur Distributary whose length is about 33 kilometers. The canal follows the ridgeline between the Baya River and Gandak River. The designed canal network for the VBC includes has two distributaries, 14 sub-distributaries, and 45 minor canals having a total length of 296 kilometers. All are ridge canals. The VBC is designed to carry a discharge of 1,304 cusecs at the head of the canal. The canals are unlined. Control structures are of masonry construction. Most gates are screw lift gates. In almost all cases, cross-regulators have been provided below canal turnouts to provide adequate head in this flat area.

As in other Indian irrigation systems, turnouts from the minor canals are called “outlets.” In the Eastern Gandak System outlets were designed to serve a wide range of areas from 16 hectares up to 120 hectares. Outlets are ungated.

It was planned that the government would construct watercourses below the outlets that carried more than 1 cusec and it was assumed that the farmers collectively would construct smaller watercourses and field channels. In fact, farmers constructed only some of the field channels. To remedy this problem, the Gandak Command Area Development Authority (GCADA) was made responsible for constructing field channels. However, GCADA has constructed only 10% of the needed field channels. Also, in many cases, outlets were not installed and farmers were forced to cut the banks to take water from the minor canals.

The designed cultivable command area of the VBC is 63,289 hectares. The planned total annual irrigated area was 75,946 hectares divided as follows: 44,302 hectares in kharif (70% of the total); 22,151 hectares in rabi (35% of the total); 5,063 hectares in summer (8% of the total); and 4,430 hectares of perennial crops (7%). The planned annual cropping intensity was 120%. However, when construction stopped in 1985, irrigation facilities had been completed only for 17,250 hectares. Thus the irrigated area is much less than designed.

The condition of the canals and control structures is not good, in part because of poor design and failure to complete construction. Many gates are broken and have not been repaired for many years. For example, in 1992-93, the screw on one minor canal headgate was broken so the gate was propped open with bricks. While the VBC itself and most of the distributaries are still in relatively good condition, many of the minor canals have been damaged by farmers cutting the banks and by other changes. To a large extent, the poor condition of the canals and control structures is due to a lack of funds for maintenance. Table 7 shows details of 3 minor canals studied in 1992-93. From this table it can be seen that failure to construct items has led to problems.
Table 7. Details of Three Sample Minor Canals (1992).

<table>
<thead>
<tr>
<th>Feature</th>
<th>Chakwa Minor</th>
<th>Madan Chapra Minor</th>
<th>Shampur Minor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position on VBC</td>
<td>head</td>
<td>middle</td>
<td>tail</td>
</tr>
<tr>
<td>Length (meters)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Designed</td>
<td>396</td>
<td>609</td>
<td>2743</td>
</tr>
<tr>
<td>Constructed</td>
<td>213</td>
<td>152</td>
<td>1524</td>
</tr>
<tr>
<td>Discharge (lps)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design Present*</td>
<td>203 much less</td>
<td>197 much less</td>
<td>313 much less</td>
</tr>
<tr>
<td>Outlets</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. planned</td>
<td>5</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>No. constructed</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>No. operational</td>
<td>0</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>No. of bank cuts</td>
<td>9</td>
<td>6</td>
<td>32</td>
</tr>
<tr>
<td>Other Problems</td>
<td>Broken culvert leaks water on road.</td>
<td>Minor not located where planned; functional length is only 900 meters.</td>
<td></td>
</tr>
</tbody>
</table>

* There are no records of discharges at minor canal heads.

Also, many watercourses and field channels constructed earlier have become inoperative because of non-use or poor maintenance. Many field channels are not in use for want of proper linking arrangement between outlets and channels constructed by GCADA. In addition, field drainage and land leveling have not been completed in the command. These were also held to be the responsibility of the farmers. In the absence of proper on-farm development, there is considerable wastage of water.

3.2. INSTITUTIONS FOR CANAL MANAGEMENT

3.2.1. Policies, Laws, and Regulations

3.2.1.1. Bihar Irrigation Laws and Written Policies

According to the Indian Constitution, management of water resources is a state subject. With regard to surface water, therefore, there are no binding national laws and, although there are a number of national policy statements and programs, notably the National Water Policy (GOI, 1987), they are not binding on the state.

On the other hand, Bihar has a number of policies, laws, and regulations concerning use of surface water for irrigation and other things. The laws and written policies dealing with irrigation include the following:

- Bengal Canals Act, 1864
- Bengal Irrigation Act, 1876
- Bengal Embankment Act, 1882
- Bihar Private Irrigation Works Act, 1922
- Bihar Public Irrigation and Drainage Works Act, 1947
- Bihar Emergency Cultivation and Irrigation Act, 1955
- Bihar Lift Irrigation Act, 1956
- Bihar Irrigation Field Channels Act, 1965
- Bihar State Water Policy, 1993

Rules and regulations have been formulated to implement the provisions of these laws.

Of these laws, the most comprehensive and important for irrigation management is the Bengal Irrigation Act, which with some of the others have been amended a number of times, sometimes in major ways.

Rather than attempt an analysis of these laws, we summarize the policies contained in them, including, where relevant, specific provisions that define irrigation management practices for canal systems in Bihar.

3.2.1.2. Actual Irrigation Management Policies

A basic principle incorporated into the Bengal Irrigation Act and held valid since is that the state has the legal right to assign use of all surface water in the state although it may not choose to do so.

Also, incorporated into the Bengal Irrigation Act of 1876 and legally mandated until 1974 was the irrigation management system generally called the “satta” system. Under the satta system, canal officers issued permits to take water, called satta, on farmers’ written requests. Double water rates were charged for unauthorized irrigation. One farmer per outlet was appointed as sattadar to oversee water distribution. He was paid 2% of the canal revenue collected in his area. The canal authorities were responsible for getting the water to the outlet and the sattadar managed distribution below the outlet. Village channels were constructed and maintained by villagers. Informants claim that water would be denied to a village if the village channels were not maintained properly. Alternatively, the canal authorities might carry out necessary repairs and charge the costs to the villagers. Assessment and collection of water rates was done by revenue wing of the Irrigation Department with help from the sattadar.

After India’s independence in 1947, water came to be regarded as common property which every individual had a natural right to use (GOI, 1987). The independent government came to view irrigation not as a commercial venture but as a form of welfare. This had three consequences:

- The government made an effort to spread irrigation to as many farmers as possible leading to heavy demands on the systems.
- Water rates were kept low, leading to inadequate revenues for operation and maintenance.
- Power to manage irrigation became more centralized in the state level bureaucracies and political entities. The powers of the field level officers were gradually reduced making it more difficult for the officers to control the system well and to punish farmers who abused the system.

Consequently, farmers began paying less attention to filing the applications for water knowing that if the monsoon failed they could always pressure the government to supply water. To do their jobs without appropriate powers, field staff, including the sattadars, started harassing farmers. The situation eventually became unmanageable and the government abolished the satta system in 1974.
Under the system introduced in 1974, farmers are not required to make applications for water. Instead, areas within the commands have been designated areas of "assured irrigation." Farmers within the areas of "assured irrigation" have the right to take water from the canals whenever it is available. Canal officers are responsible for preparing water schedules and informing farmers which canals are open and for what duration. Water distribution below the outlet remains the responsibility of the farmers, but the position of the sattadar has been abolished. Water rates are assessed on all land within the "assured irrigation" area whether or not the land is irrigated.

This system has not been a success. Since permits are not required, there is no definition of unauthorized irrigation. Thus farmers in the upper areas can take as much water as they want irrespective of the needs of farmers lower down the system. In addition, the weak financial and managerial powers of the canal officers encourage abuse of water by farmers and reluctance by officers to visit the canals.

Therefore, for some time, there has been discussion about changing the law and the policy, as well as some experiments. One experiment was the reintroduction of the satta system in 1988 in the Sone System, without notable success. Another was the experiment in participatory irrigation management carried out by the Water and Land Management Institute in the Paliganj Distributary in the Sone System (Srivastava and Brewer, 1994). Also, Bihar constituted an Irrigation Commission to review policies, laws, actions, and other items. The Commission issued its report in six volumes in 1994 (GOB, 1994).

The Commission recommended some major changes, including:

- Abolition of the "assured irrigation area" principle; it recommended requiring farmers to apply for water each season and then only charging water rates for farmers who apply.
- Giving more operations and maintenance responsibilities to organized farmers.

The state is now attempting to implement an irrigation management transfer program modeled on the Paliganj experiment.

3.2.2. Water Resources Department (WRD)

3.2.2.1. WRD Organization for the Eastern Gandak Command

The Water Resources Department (WRD) is responsible for management of the canals down to the outlets. Currently, there are two Chief Engineers in charge of operation and maintenance of the Eastern Gandak System. One is headquartered at Motihari in charge of the main canal from the headgate to a regulator located at about 164 kilometers from the head of the TMC, and the other is stationed at Muzaffarpur in charge of the canal from that point to the end of the TMC. These Chief Engineers have nine and four divisions, respectively under their jurisdictions. For every four divisions one Superintending Engineer has been appointed. An Executive Engineer, who has four sub-divisions under his jurisdiction, heads each division.

A Superintending Engineer who oversees the operation and maintenance of the barrage and canal headworks heads the barrage office at Valmikinagar. His responsibilities include not only the civil engineering aspects but also the mechanical and electrical engineering aspects as well. A manual for the operation and maintenance of the barrage and canal headwork gates serves as the primary guide for staff. Other guidelines are issued periodically.
The sub-divisional office is the lowest administrative level of the Water Resources Department in the Gandak Project. The sub-divisional office is generally located at block headquarters and is headed by a Sub-Divisional Officer who is an Assistant Engineer. This officer is generally in charge of an area of 15,000 to 20,000 hectares and has four Junior Engineers to assist him, each in charge of 4,000 to 5,000 hectares. Junior Engineers keep track of water discharges in distributaries and minors and irrigated area in the minors. They are also expected to regularly check the physical condition of the distribution network.

Junior Engineers are assisted by Amins, whose main responsibility is to ensure timely supply and distribution of canal water below the minors. At the end of the season, Amins make a record of fields irrigated by canal water with their relevant revenue survey numbers and send these records to the revenue office at the block level, which in turn prepares the water revenue report based on the fields irrigated.

The WRD also has a number of daily workers, generally called canal mates, to operate gates and carry out small maintenance tasks.

WRD personnel responsible for canal operations are not perceived to be efficient and effective (cf Srivastava and Brewer, 1994). One problem is that neither Executive Engineers nor Assistant Engineers are provided with work charts or operational guidelines to enable them to discharge their duties efficiently. In the absence of well-defined operational rules and guidelines, officers have to depend on oral and written instructions from higher-level officers. Transfers within the Department from one area of responsibility to another, for example from construction to operation or from groundwater to design, frequently take place without the benefit of prior familiarization training. This too tends to reduce the efficiency of the officers.

3.2.2.2. WRD Management Organization for the VBC

The Executive Engineer, Saraya Division, is the WRD officer in charge of the Vaishali Branch Canal. For operation and maintenance of the system, there are six Sub-Divisional Officers as listed below:

- Sahebganj Sub-Division: VBC from headgate to 11.3 km, Chainpur Sub-Distributary
- Deoria Sub-Division: VBC from 11.3 km to 23.9 km, Mija Sub-Distributary, Saraya Sub-Distributary, Keshopur Sub-Distributary
- Paroo Sub-Division: VBC from 23.9 km to 42.1 km, Bishunpur Sub-Distributary, Laloo Chapra Minor, Paroo Sub-Distributary
- Saraya Sub-Division: VBC from 42.1 km to 47.2 km, Habibpur Sub-Distributary, Hazipur Sub-Distributary
- Vaishali Sub-Division: Bhagwanpur Distributary from headgate to 12.7 km
- Lalganj Sub-Division: Bhagwanpur Distributary from 12.7 km to 32.6 km, Prataptpur Sub-Distributary

The Executive Engineer and the Sub-divisional Officers in charge of Saraya and Vaishali live at the divisional colony in Saraya whereas other Sub-Divisional Officers live at Headquarters in Muzaffarpur.
3.2.2.3. Operational Problems of the WRD Field Staff

The WRD field is hampered greatly in carrying out its functions, not only by the poor conditions of the canals and structures, but also by lack of other needed facilities, particularly transport and communications facilities. For example, in 1992, the Saraya Executive Engineer did not have a functioning vehicle to go to the field. Nor did he have a functioning telephone.

This lack of facilities is largely caused by a financial crisis within the Government of Bihar. Bihar's poverty extends not only to the general populace but also to the government. All aspects of operations and maintenance of the canal systems in Bihar are under funded.

3.2.3. Gandak Command Area Development Authority

The Gandak Command Area Development Authority (GCADA) was established in 1975 as the nodal agency for the integrated rural and agricultural development of the whole Gandak Command area. The Authority's 1991/92 Annual Report states that it has been engaged in activities designed to promote coordination among the different departments involved in rural and agricultural development. The Report also states that it has endeavored to facilitate maximum utilization of available irrigation facilities by implementing on-farm development programs in the Project. In reality, GCADA's only major activities are the construction of lined and unlined field channels and on-farm development. Field inquiries indicate that financial and administrative constraints have prevented GCADA from effectively fulfilling its functions. GCADA has also suffered from a lack of efficient leadership.

3.2.4. Local Institutions and Customs

Operations and maintenance below the outlets is supposed to be the responsibility of the farmers collectively. Except where the state's new participatory management program is in place, there are no recognized formal organizations that take on this function.

As in most of India, the accepted conceptual bases for cooperation include caste, kinship, village, and faction (Leaf, 1998). Neither caste nor village is really suitable since membership does not coincide with those who hold land under a given outlet. Factions are formed within villages for political purposes; they rarely can be called upon to organize cooperative efforts. Only kinship is an effective basis for organizing collective action at the required scale.

There are no legally recognized water rights. Under the "assured irrigation area" policy, not even payment of fees gives a farmer a claim to irrigation water. Nor are there generally recognized customary principles for distribution of water.

3.3. Canal Management Methods

3.3.1. Water Allocation

The WRD O&M officers strive to determine water demand and allocate water every 10 days during an irrigation season. The basic pattern is as follows:

1. Each Junior Engineer attached to a Sub-Divisional office determines the demand in his area. He does this based on his knowledge of customary need; no field surveys or consultations with farmers are carried out.
2. The Junior Engineer forwards this demand to the Sub-Divisional Officer, who consolidates the demands from his Junior Engineers.

3. The Sub-Divisional Officer forwards the consolidated demand to the Executive Engineer in charge of the division who consolidates demands from his sub-divisions.

4. The divisional Executive Engineers send the consolidated demand to their respective Chief Engineer's office - in Motihari for the upper portions of the Eastern Gandak System or in Muzaffarpur for the lower portions - where the divisional demands are consolidated.

5. The Chief Engineers' offices send these consolidated demands to an Executive Engineer located in Betiah who prepares a consolidated demand for the whole Eastern System.

6. This Executive Engineer then sends the final consolidated demand to the headworks of the Eastern Main Canal at Valmikinagar.

Indents for water have to be made 13 to 15 days in advance by the Junior Engineers in the field due to communication problems. The Executive Engineers prepare demand estimates 10 to 12 days in advance and the Chief Engineer's offices eight to 10 days in advance. The consolidated demand reaches the headworks six to eight days in advance of actual releases into the canal.

Because the demands have to be prepared so far ahead of time, there is no possibility of taking rainfall or field conditions into account. Rainfall data is collected and maintained by the Block Development Office but not used for planning irrigation. There is also a general feeling that rainfall predictions are misleading. Rainfall does affect operations; some gates are closed when there is excess rain.

3.3.2. Operation of the Headworks and the Main Canal

The head regulators for the Gandak main canals are located downstream of the barrage. Water for irrigation is made by releasing water to the river, which is then picked up at the canal headworks. When water is to be discharged into the river to be picked up at the canal head regulators, the under sluice gates on both sides of the barrage are opened first. If there is a further need to allow water to flow downstream, the center gates are also opened. The side gates are opened in the last.

As noted above, the consolidated demand for the Eastern Gandak system for a 10 day period is communicated to the engineer in charge of the barrage who opens the canal headgates the proper amount to provide the requested amount of water.

Flow in the river is measured continuously to aid in operations and to protect the system. The barrage gates are supposed to be operated to allow excess water to flow downstream without damaging the barrage or interfering with canal operations. As an emergency measure, the canal headgates are closed whenever river flow exceeds 450,000 cusecs (about 12,740 cusecs).

Silt load in the Gandak River is a problem. To provide an accurate assessment of the silt load factor there is a standing order to record measurements of silt load at three hourly intervals. Samples are collected by the Barrage Division and tested by the Quality Control wing. Results are to be communicated to Operations within two hours for action. If the silt load is high, canal headgates
are supposed to be closed to prevent excess silt from entering the canals. Unfortunately, this system does not work because:

- The instrument used to collect samples is not functioning effectively and samples cannot be taken at the desired depth,
- Samples are neither sent speedily to the laboratory nor are they attended to quickly when they are received, resulting in test results not being taken into consideration in canal gate operations,
- Supervision is inadequate.

Although silt from the pond area is propelled into the river by silt excluders, improper detection and handling of silt has resulted in canal water becoming heavily silt-laden. There is no provision for a silt ejector in the Eastern Main Canal and this has caused heavy siltation of the canal bed and has considerably reduced canal capacity. Also a heavy deposit of river boulders and concrete debris is evident for a considerable length along the head reach of the Eastern Main Canal, having found its way into the canal through ineffective control at regulation points. The concrete debris comes from damaged canal lining and from rubble left behind by the contractors.

Theoretically, the various engineers along the TMC have their staff operate the branch and distributary canal headgates and the cross-regulators so that the desired amount of water flows into each canal for that 10-day indent period. In fact, it is reported that for the most part, off-takes from the TMC are left open all the time except when farmers demand that they be closed. That is, the TMC is not operated as it is supposed to be.

3.3.3. Operation of the Vaishali Branch Canal

As noted above, the headgate of the VBC is usually left open; then whenever there is water in the TMC, it flows into the VBC. Normally water is allowed to flow continuously from the VBC into the sub-distributaries and minor canals taking off from the VBC and thence into lower level canals. However, for much of the time, the flow into the VBC is not adequate to provide the head needed to enter all the off-taking canals, the cross-regulators have to be adjusted to provide the needed head.

In times of tight supply, the WRD staff tries to implement rotations on the VBC. Generally the rotation plan is that water is allowed to go to the tail portion of the VBC (below the cross-regulator at 31 km) for four to six days and then to the head portion for the same amount of time.

In times of water shortages, farmers in some parts of the VBC command (for example Madan Chapra Minor Canal in the middle reach of the VBC) have been known to organize to take action to force the WRD officers to give them water. Such actions have included dragging the WRD officers to the site to show them the problems, picketing the WRD officers, and more direct interference with operations. Canal authorities have had to call in police to maintain order at times.

All structures have been calibrated, no regular flow measurements are taken below the heads of the branch canals. Also, because of poor construction and maintenance, the calibrations may well be wrong.

3.3.4. Water Distribution below the Outlets

Since outlets, or bank cuts, are ungated, water flows continuously through the outlets whenever water is available in the minor canal. Where the field channels do not exist, water has to flow from field to field or it simply floods the upper fields.
Where watercourses and field channels exist, farmers generally cooperate to distribute water below outlets to the extent that they develop a customary order for taking water below each outlet. This may be from head to tail, or it may be that the most powerful person takes water first, etc.

With regard to maintenance, each farmer is supposed to be responsible for cleaning and maintaining the section of field channel that abuts his fields, but there is little ability to enforce this principle. The result is wide variation in ability to maintain field channels; farmers that have some reason to cooperate, such as kinship, may do a reasonable job, while others do not.

3.4. CANAL WATER DISTRIBUTION PERFORMANCE

3.4.1. Water Deliveries to the Vaishali Branch Canal

Because of inefficiencies in water allocation and the various physical and organizational problems of the WRD, water availability in the Tirhut Main Canal varies greatly; the lower portions get far less water than the upper portions. For operational purposes, the TMC is divided into an upper portion from its head to a cross-regulator at kilometer 163.7, and a lower portion under the Mazaffarpur Divisions from the cross-regulator to the end of the canal. Under the standing orders of the system, the TMC is to be operated on the following schedule:

<table>
<thead>
<tr>
<th>Season</th>
<th>Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kharif</td>
<td>20 May to 20 October</td>
</tr>
<tr>
<td>Rabi</td>
<td>1 December to 10 March</td>
</tr>
<tr>
<td>Hot Weather</td>
<td>10 April to 19 May</td>
</tr>
</tbody>
</table>

Though water is abundant at the headworks during kharif, tail end farmers nevertheless suffer due to defects in the water distribution network. The TMC upper portion is unable to carry simultaneously the indents of the upper reach and the lower reach. The result is the upper reach receives most of the canal water during the day and the lower reach during the night. Most farmers do not irrigate at night so much of the water either goes waste or floods the fields.

The overall amount of water supplied to the Vaishali Branch Canal, which is is the TMC tail portion, is well under the amount requested. Table 8 shows the indents and amounts supplied to the VBC during kharif 1992. In 1992, as shown in this table, during June, July, and August, when demands are highest, the VBC got less than 75% of the indent. Yet in September, when demand drops sharply as the paddy crop ripens, the VBC got over 300% of requirements.

Table 8. Indents and Amounts Supplied at Head of Vaishali Branch, Kharif 1992 (acre-feet).

<table>
<thead>
<tr>
<th>Month</th>
<th>Indent</th>
<th>Amount Supplied</th>
<th>Percent Supplied</th>
</tr>
</thead>
<tbody>
<tr>
<td>June 1992</td>
<td>9,000</td>
<td>5,566</td>
<td>62 %</td>
</tr>
<tr>
<td>July 1992</td>
<td>23,400</td>
<td>16,556</td>
<td>71 %</td>
</tr>
<tr>
<td>August 1992</td>
<td>21,600</td>
<td>13,212</td>
<td>61 %</td>
</tr>
<tr>
<td>1 to 23 Sept 1992</td>
<td>3,000</td>
<td>9,248</td>
<td>308 %</td>
</tr>
<tr>
<td>Total</td>
<td>57,000</td>
<td>44,582</td>
<td>78 %</td>
</tr>
</tbody>
</table>
Figure 3 shows the indent and actual discharge at the head of the Vaishali Branch Canal for August 1992. As shown the flow is above the indent in the early part of the month, but far below in the middle of the month when needs are the highest and then far above at the end of the month when needs fall. There is only the vaguest relation between indent and actual discharge; users upstream get the water when farmers want water while downstream users get it when they do not want it.

Figure 4 shows the deliveries to the head of the VBC over kharif 1998. As in 1992, deliveries are very erratic and include both too little water at various times and far too much water late in the season.

The lower reach of the Tirhut Main Canal was planned to irrigate a cultivable command area of 154,000 hectares. However, because of the construction halt in 1985, distribution facilities have been provided only for 40,412 hectares. As a result, the maximum possible demand of the lower reach is around only 26 percent of designed capacity. Thus the canal can carry well over the possible demand. Also, the Government allocates funds for maintenance based on the irrigated extent of the division. Because the Muzaffarpur Division has a long length of canal and little irrigated area from which no direct irrigation is done, the canal is deprived of much needed maintenance funds.

Although water is available in the Gandak River, these factors make water deliveries to the Vaishali Branch Canal unpredictable and unreliable from day to day. While in general delivering too little water when demand is high and too much when demand is low or non-existent near the end of the season.

3.4.2. Performance of the Vaishali Branch Canal

The VBC's design discharge is 1304 cusecs. As shown in Figures 3 and 4, the VBC runs at 30 to 32 percent of design discharge at the maximum. During the last several years, maximum discharge during the kharif season has ranged between 400 and 450 cusecs. During the Rabi season, it ranged between 250 and 300 cusecs. The highest discharge recorded at this regulator has been 978 cusecs during the 1978 kharif season.
Figure 3. Indent and actual discharge at Vishali Branch Canal Head, August 1992.

At present, because of deterioration, the carrying capacity of the canal is 500 cusecs, which though capable of irrigating 14,000 hectares, in actuality only irrigates at most 10,000 hectares during kharif. A former Executive Engineer of the Vaishali Branch Canal and later Chief Engineer of the Gandak Project said that during his tenure between 1975 and 1978, canal discharge was 600 to 900 cusecs. It is evident that the system has deteriorated considerably through the lack of proper and adequate maintenance.

Table 9 shows the areas that were, according to the plan, to be irrigated by the VBC. Actual areas irrigated are much less, partly because of failure to construct the distribution system, but also because of the unreliability of the irrigation water supply.

Table 9. Planned Annual Irrigation from the Vaishali Branch Canal.

<table>
<thead>
<tr>
<th>Season</th>
<th>Area (ha)</th>
<th>% of CCA</th>
</tr>
</thead>
<tbody>
<tr>
<td>kharif</td>
<td>44,302</td>
<td>70 %</td>
</tr>
<tr>
<td>rabi</td>
<td>22,151</td>
<td>35 %</td>
</tr>
<tr>
<td>summer</td>
<td>5,063</td>
<td>8 %</td>
</tr>
<tr>
<td>perennial</td>
<td>4,430</td>
<td>7 %</td>
</tr>
<tr>
<td>Total</td>
<td>75,946</td>
<td>120 %</td>
</tr>
</tbody>
</table>
Figure 4. Deliveries to Vishali Branch Canal, Kharif 1998.

The area irrigated by canal water as reported by the Water Resources Department at the end of a season is considered the "achieved area" for the season. This is measured against the "target area" fixed at the beginning of the season. The achieved area is often less than the target area. Table 10 shows the target irrigated areas and the "achieved areas" for the VBC for from 1978-79 through 1992-93 and for 1998-99. If these are compared with the target areas, achievements range from 2% to 120% of target areas. Performance is bad even by the WRD's own standards.
Table 10. Target and Achievement Area in Vaishali Branch Canal (ha).

<table>
<thead>
<tr>
<th>Year</th>
<th>Kharif Target</th>
<th>Kharif Achieved</th>
<th>% Target</th>
<th>Rabi Target</th>
<th>Rabi Achieved</th>
<th>% Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>1978-79</td>
<td>9,775</td>
<td>185</td>
<td>2 %</td>
<td>1,360</td>
<td>32</td>
<td>2 %</td>
</tr>
<tr>
<td>1979-80</td>
<td>12,826</td>
<td>3,590</td>
<td>28 %</td>
<td>800</td>
<td>956</td>
<td>120 %</td>
</tr>
<tr>
<td>1980-81</td>
<td>13,600</td>
<td>8,900</td>
<td>65 %</td>
<td>2,700</td>
<td>1,800</td>
<td>67 %</td>
</tr>
<tr>
<td>1981-82</td>
<td>11,800</td>
<td>12,980</td>
<td>110 %</td>
<td>3,780</td>
<td>2,860</td>
<td>76 %</td>
</tr>
<tr>
<td>1982-83</td>
<td>14,500</td>
<td>15,790</td>
<td>109 %</td>
<td>4,300</td>
<td>3,960</td>
<td>92 %</td>
</tr>
<tr>
<td>1983-84</td>
<td>16,500</td>
<td>18,795</td>
<td>114 %</td>
<td>4,990</td>
<td>2,879</td>
<td>46 %</td>
</tr>
<tr>
<td>1984-85</td>
<td>19,000</td>
<td>15,096</td>
<td>79 %</td>
<td>na</td>
<td>na</td>
<td>-</td>
</tr>
<tr>
<td>1985-86</td>
<td>16,290</td>
<td>na</td>
<td>-</td>
<td>2,700</td>
<td>442</td>
<td>16 %</td>
</tr>
<tr>
<td>1986-87</td>
<td>22,000</td>
<td>6,628</td>
<td>30 %</td>
<td>3,810</td>
<td>3,390</td>
<td>89 %</td>
</tr>
<tr>
<td>1987-88</td>
<td>15,000</td>
<td>6,625</td>
<td>44 %</td>
<td>7,500</td>
<td>2,975</td>
<td>40 %</td>
</tr>
<tr>
<td>1988-89</td>
<td>14,000</td>
<td>6,993</td>
<td>50 %</td>
<td>7,000</td>
<td>2,514</td>
<td>36 %</td>
</tr>
<tr>
<td>1989-90</td>
<td>14,000</td>
<td>6,313</td>
<td>45 %</td>
<td>6,212</td>
<td>2,591</td>
<td>42 %</td>
</tr>
<tr>
<td>1990-91</td>
<td>16,720</td>
<td>9,097</td>
<td>54 %</td>
<td>7,700</td>
<td>1,217</td>
<td>16 %</td>
</tr>
<tr>
<td>1991-92</td>
<td>16,720</td>
<td>9,490</td>
<td>57 %</td>
<td>2,500</td>
<td>2,271</td>
<td>91 %</td>
</tr>
<tr>
<td>1992-93</td>
<td>15,000</td>
<td>10,005</td>
<td>67 %</td>
<td>2,500</td>
<td>2,010</td>
<td>80 %</td>
</tr>
<tr>
<td>1993-94</td>
<td>10,000</td>
<td>6,675</td>
<td>67 %</td>
<td>2,510</td>
<td>816</td>
<td>33 %</td>
</tr>
</tbody>
</table>

4. MANAGING GROUND WATER USE IN THE VBC COMMAND

4.1. TECHNOLOGY FOR GROUND WATER USE

The following discussion is taken largely exclusively from our 1992-93 study. However, there were no reported changes in tubewell technology between that time and 1999.

4.1.1. Types and Distribution of Wells in the VBC Command

Ground water for irrigation is derived largely from three types of wells: shallow tubewells (STWs) with depths less than 150 feet, deep tubewells (DTWs) with depths more than 150 feet, and dug wells (open wells). Within the state of Bihar, the Minor Irrigation Department estimated in 1990 that there were about 5790 deep tubewells, 593,540 shallow tubewells and about 396,640 dugwells (with or without pumps) used for irrigation. The total irrigation potential envisaged through these schemes was 2.98 million hectares.

While the number of deep tubewells has not increased significantly and the number of dugwells may have decreased the Department estimates that perhaps, another 300,000 shallow tubewells have been installed since 1990. For reasons given later, this may be an overestimate of the number of STWs installed since 1990.

All three types of wells are found in the VBC area. Table 11 shows the numbers of such wells reported in 1991 for the six blocks in which the VBC Command falls. As shown in Table 8, STWs predominate. Out of 1844 wells for irrigation reported in 1991, 71% are STWs and only 3% are DTWs. According to our 1999 interviews, the number of DTWs has not changed since 1992 and the number of STWs has increased but not to a large extent, perhaps 10-15% only.


<table>
<thead>
<tr>
<th>District</th>
<th>Block</th>
<th>Dugwells</th>
<th>Shallow Tubewells</th>
<th>Deep Tubewells</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muzaffarpur</td>
<td>Paroo</td>
<td>-</td>
<td>309</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Saraya</td>
<td>-</td>
<td>232</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Sahabganj</td>
<td>18</td>
<td>164</td>
<td>4</td>
</tr>
<tr>
<td>Vaishali</td>
<td>Lalganj</td>
<td>128</td>
<td>275</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>Hazipur</td>
<td>221</td>
<td>235</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Vaishali</td>
<td>9</td>
<td>194</td>
<td>8</td>
</tr>
<tr>
<td>Totals</td>
<td></td>
<td>376</td>
<td>1409</td>
<td>59</td>
</tr>
</tbody>
</table>

These blocks are either fully or partly irrigated by the Vaishali Branch Canal.
Sources: Respective Block Development Offices, 1991.

Based on interviews carried out in 1992-93, in the 1960's there were very few tubewells and there were a large number of dug wells used for irrigation. All of these have been replaced by STWs except in a few areas. Because of the limited distribution and the trends, we will not discuss use of dugwells here.
4.1.2. Characteristics of Shallow Tubewells in the VBC Command

Two kinds of STWs are found in the study area: filter wells and cavity wells:

- Pipes for a filter well include sections of blind pipe and sections of perforated or filter pipe, both made from mild steel. The filter pipe is installed in the sandy water-bearing strata to allow for inflow of water. In the filter pipe is installed a strainer to keep out sand which would harm the pump and make the water less valuable for irrigation. All private filter wells in the study area are sand packed. Filter wells are fitted with either coir rope strainers or bamboo strainers. The coir rope strainers are low-cost screens for shallow tubewells. The screen is formed by winding a coir rope of three to five mm diameter around a circular array of mild steel rods. The frame is strengthened at intervals with iron rings. The surface of the coir acts as a sieve, which allows water to pass while filtering out sand. The bamboo strainer is essentially a coir rope strainer whose support frame is made of bamboo strips instead of steel rods. Bamboo strips are laid out lengthwise and fixed to mild-steel rings of 10 to 12 cm diameter placed at 30 cm intervals. Coir rope is then wound around the cylindrical frame. The bamboo strainer was originally developed in Bihar and became popular as a low-cost filter for shallow tubewells throughout the Gangetic Plains of Bihar and West Bengal (Khepar, 1989).

- Putting blind pipe down to the top of the water-bearing stratum well makes a cavity. Then a rod or other instrument is used to stir the area just below the pipe after which the resulting mixture of sand, mud, and water is pumped out. After several repetitions of this procedure, a hemispherical cavity is created just below the end of the pipe, the size of which depends upon how much time and effort has been used in the process of creating the cavity. In theory, all of the fine sand near the cavity has also been removed and the remaining coarser particles serve as a strainer to keep out fine particles from further away.

Details of the wells studied in 1992-93 are given in Table 12.

4.1.3. Characteristics of Deep Tubewells in the VBC Command

Most DTWs in the VBC area are operated by the state and have been located in higher areas and other areas outside the potential command of the VBC. These are not discussed here.
Table 12. Shallow Tubewell Characteristics in the Sample Minors.

<table>
<thead>
<tr>
<th>Particulars</th>
<th>Chakwa</th>
<th>Madan Chapra</th>
<th>Shampur</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of well</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Cavity</td>
<td>7</td>
<td>11</td>
<td>19</td>
</tr>
<tr>
<td>- Filter</td>
<td>-</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>Average depth (ft)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Cavity well</td>
<td>73</td>
<td>63</td>
<td>63</td>
</tr>
<tr>
<td>- Filter well</td>
<td>-</td>
<td>54</td>
<td>52</td>
</tr>
<tr>
<td>Average pipe length (ft)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Filter pipe</td>
<td>-</td>
<td>32</td>
<td>22</td>
</tr>
<tr>
<td>- Blind pipe</td>
<td>-</td>
<td>22</td>
<td>30</td>
</tr>
<tr>
<td>Packing for filter wells</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Sand pack</td>
<td>-</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>- Gravel pack</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Pipe diameter</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 4 inch</td>
<td>7</td>
<td>18</td>
<td>25</td>
</tr>
<tr>
<td>- 3 inch</td>
<td>-</td>
<td>2</td>
<td>-</td>
</tr>
</tbody>
</table>

However, there are a number of DTWs installed by the Vaishali Small Farmers Association (VASFA) located within the VBC Command. VASFA and its imitators are discussed in more detail below. Four such wells are located in the Shampur Minor, our 1992-93 tail site.

The average depth of these four DTWs is 185 feet. All are filter wells and the average length of filter pipe is 60 feet. All have gravel packing. Two have 4-inch pipes and two have 6-inch pipes. All are fitted with 5 horsepower diesel pumpsets.

4.1.4. Pumpsets

In the study area, 41 of the 52 STWs are fitted with pumpsets. All four of the DTWs have pumpsets. These have the following features:

- All pumpsets consist of centrifugal pumps fitted with single cylinder five-horsepower diesel engines. Since electrical power is only supplied for between one and two hours a day, no electrical pumpsets have been installed.
- Most pumpsets have been installed on small wooden carts, which can be towed away by bullocks to prevent theft. A few have been installed on wooden beams so that they can be manually lifted onto bullock carts. The DTW pumpsets are permanently mounted in small buildings.
- The diesel engines have rated speeds of 1500 rpm. It was not possible to obtain a rpm-measuring meter to observe functional speeds.
- The display plates on the diesel engines provide the following information:
  - Engine efficiency is 64 percent
  - Head range is 16.4 to 26.25 feet
- Fuel consumption is 247 grams per hour (translating to a fuel consumption of 1.008 liters per hour)
- Various makes of pumpsets are in use. The most popular is the Bharat, 19 of the 41 STW pumpsets are Bharat. The remaining 22 STW pumpsets are of 11 different makes, including Bharatshakti, India and Usha, Kirloskar, Atul Shakti, Harvest, Peter, Wilson, Sathyam, Super Bharat and GEF 500. Dealers said that only one out of these 12 makes is manufactured in Bihar.
- The height of the pumpset base is normally determined by the height of a pipe T-section installed at the top of the tubewell pipe. Field measurements indicate that the average installation height of a pumpset is 15 inches in Chakwa Minor, 12 inches in Madan Chapra Minor and 8.5 inches in Shampur Minor. Although this seems to indicate a decline in height from head to tail along the VBC, the reasons for this relationship, if any, between location and height of installation could not be determined.

Making the pumpsets portable is an important feature since it makes it possible to use a pumpset on more than one bore or for purposes unrelated to the tubewell. One tubewell and pumpset owner, not in the sample area, explained that he used his pumpset not only for irrigation but also for fishing in the shallow depression near his village (by pumping water out of shallow separated sections they can strand fish to be picked up by hand).

4.1.5. Tubewell Installation

4.1.5.1. Location of Wells

Farmers generally select elevated points to facilitate gravity flow to the fields. The points are generally not in the middle of a single farmer's land, but on the edge to facilitate use of water by others.

4.1.5.2. Drilling Methods

A local driller called "mistry." undertakes borings for STWs. When a farmer hires a mistry, the mistry normally decides the method of installation based on his experience in the village or nearby areas. Also, he usually manages with boring instruments available to him. Normally, he uses a sludge, a hand auger and a wrench. If he does not have these instruments or if he gets more than one job, then he borrows what he needs from other mistris by paying a nominal fee. Occasionally, he can borrow instruments from a friend.

The mistry's chosen method of boring and his choice of instruments is strongly influenced by the soil strata of the location selected. These strata are closely observed during the boring process. Most tubewell owners can vividly recall the soil strata discovered during installation and are well able to describe the different kinds of soil and relevant depths.

Boring is done by means of an earth auger turned by hand. Hand augers are used to penetrate soils that will retain the open hole up to 10 meters deep, including clay, silt and some kinds of sand. Forcing the blades of the spiral or worm auger into the soil by rotating the auger commences boring. When the space between the blades is filled with soil, the auger is lifted out and emptied. This operation is repeated until the hole is bored to the required depth. For deeper wells, a tripod with a pulley block at the top is provided to insert larger auger rods into the hole and lift them out again without difficulty. Once the well hole has been bored, well screens are installed in the water bearing formation.
Drilling methods for the VASFA DTWs were the same hand methods used for private tubewells except that VASFA provided a hydraulic drill for part of the drilling of the VASFA wells.

4.1.5.3. Installation History

Table 13 shows the periods in which the 52 STWs and 4 DTWs studied in 1992-93 were installed. All were installed since 1970. However, the DTWs were installed only in the early period (1971 to 1973). All subsequent installations have been STWs. The spurts of installation correspond with various subsidy programs.

Table 13. Installation History of Tubewells in the Study Area (to 1992).

<table>
<thead>
<tr>
<th>Period</th>
<th>STWs</th>
<th>VASFA DTWs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Chakwa</td>
<td>Madan Chapra</td>
</tr>
<tr>
<td>1970-75</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>1976-80</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>1981-85</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1986-90</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>1991-92</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Totals</td>
<td>7</td>
<td>20</td>
</tr>
</tbody>
</table>

4.1.5.4. Costs of Installation

The cost of installation of a tubewell includes the costs of a) pipe and strainer, b) the labor of boring the well, and c) a pumpset. Installing and equipping tubewells in the study area has been greatly influenced by the sources of finance available, including subsidies, loans, and private resources.

In 1992-93, the average costs reported by the sample STW owners was:

- Pipes: Rs 1904
- Diesel pumpset: Rs 4344
- Labor for boring: Rs 441

For a total average cost of Rs 6518.

Diesel pumpsets are much more expensive than tubewell pipes. If a farmer owns a tubewell he can always hire a pumpset. For these reasons, while 51 farmers individually own tubewells, only 40 of them own pumpsets. Others rent pumpsets from nearby pump owners or from outside the village.

The average installation costs of the VASFA DTWs were:

- Pipes: Rs 5910
- Diesel pumpset: Rs 5950
- Labor for boring: Rs 3293
For a total average cost of Rs 15,153.

The large difference between the cost of installation of the STWs and DTWs is caused by the greater depth - the DTWs average 195 feet deep while the STWs average 62 feet - and use of gravel packing instead of sand packing.

It should be noted, however, that these figures do not represent the present cost of STWs and DTWs since these figures have not been converted to constant rupees and the sample tubewells were installed over the period of 1971 to 1989.

4.1.6. Tubewell Performance

During field visits, it was observed that tubewell discharge varied. Therefore, it was decided to test the functional efficiency of the pumpsets.

The 45 functional diesel pumpsets in the study area were surveyed. The slant of the pumpsets was measured to determine whether the pumpset was horizontal or slanted towards the engine or towards the pump. We found that 32 of the 45 pumpsets were placed in an improper position. Seventeen of the pumpset owners felt that by tilting the pumpset one to two inches towards the pump it would work better and draw water more quickly. On the other hand, 15 pumpset owners felt that by tilting the pumpset toward the engine, water would reach the outlet more quickly. Tilting the pumpset seems to seriously affect maintenance costs; tilting either direction increases maintenance requirements (Raju et al. 1994).

It was possible to test the functioning of 26 of the pumpsets. Each of the 26 owners operated the pumpset on request. For each, the following were measured:

- The groundwater table,
- The rate of diesel consumption,
- The discharge of the pump,
- The quantity of sand in the water.

To measure the groundwater table, an ordinary thread with a small stone tied at one end was used. The thread was allowed to drop slowly in the tubewell until it reached water. Diesel consumption was measured by taking measurements in the diesel tank before and one hour after operation of the engine. Discharge measurements were made by measuring the time taken to fill a 165-liter drum. To measure the quantity of sand in the water, sand particles were allowed to settle for 10 minutes in a water drum, then collected and measured. Water was first allowed to flow into field channels for 20 to 30 minutes before being collected in the drum.

Though the methods used were crude, they nevertheless yielded interesting results and the owners of tubewells were happy to learn the actual discharge of their tubewells and just how efficient their machines were, particularly since the testing was free of charge. The results can be summarized as follows:

---

2 The testing of the tubewells reported here and later in this chapter was done with the help and guidance of Dr. David R. Purkey, a consultant hired to help specifically with this. See Purkey (1992).
• Fuel consumption averaged 1.03 liters per hour and ranged between 0.800 liters per hour to 1.600 liters per hour.
• Water discharge averaged 9.2 liters per second and ranged from as low as two liters per second to 12 liters per second.
• In some of the tubewells, there was 70 grams of sand per 100 liters of water. The average quantity of sand per 100 liters of water was 36 grams.

4.1.7. Conditions of the Wells and Pumpsets

All of the 4 DTWs in the sample function well. Six of the 52 STWs in the sample - two in Chakwa Minor, one in Madan Chapra Minor, and three in Shampur Minor - were unused in 1992-93. In three cases the boring itself was the problem - one had a filter blocked with sand, one cavity well was undeveloped, and one cavity seems to have caved in. In two cases, the owner did not have a pumpset and did not want to rent one. In one case, three brothers who had fought among themselves in 1982 and had left the well unused since that time had jointly owned the well. This suggests that the physical condition of the bores is good. Also, only two of the 45 pumpsets were not working in 1992-93, hence it seems that they are reasonably well maintained.

4.1.8. Tubewell Water Distribution Facilities

Almost all tubewell water is conveyed to the fields through temporary or permanent earthen channels. Many places along the bund of the Shampur Minor have been carved out as unlined field channels to convey tubewell water. Roads have also been cut for the same reason. Those who cut roads and canal bunds do not seem to feel there is anything illegal in what they are doing. According to them, "it is purely a matter of convenience." PVC pipes or mild steel pipes and sometimes, underground cement pipes are also used to convey tubewell water. For the most part, the canal system channels are not used since they are so poorly developed. Lining channels for tubewell water, installing underground pipelines, or using PVC pipes laid on the ground are rare although known to be more efficient. The main reason is that pipes or lining are considered costly.

In addition, highly fragmented land holdings make it difficult for a tubewell owner to locate his well so that he can reach all of his fields without crossing someone else's land. If a channel must cross someone else's land, the landowner generally demands water at discounted rates as compensation. Also, for those well owners who sell their water, there is no assurance that today's buyer will continue to buy in the future. In these situations, most farmers prefer temporary channels rather than making a major investment lying on someone else's land.

Thirty of the 46 owners of functioning tubewells in the study area convey water to their fields through unlined field channels only; the remaining 16 convey water partly with PVC pipes and partly through unlined field channels. Only five tubewell owners have their own PVC pipes averaging 100 feet in length. Others rent pipes from nearby towns at Rs 10 per 100 feet per day (1992 prices). Damage to pipes is charged at replacement cost. Distances to fields are often much greater than 100 feet so many rent more pipe in addition to using their own to supplement the field channels.

Little investment in distribution has been made for the DTWs. Two of the DTWs have unlined field channels only. Two DTWs have lined channels on one direction for 30 and 40 feet respectively. No pipes are used. In one VASFA DTW, we measured travel time from the discharge point to a nearby user's field. The distance was 278 feet; the time taken to reach the field when water is first
pumped into the dry field channel was 21 minutes. This meant that the user was paying an hour’s pumping charges for the first hour but getting only 39 minutes of water. The user commented that “others have fields in far more distance and it takes more than an hour to reach their fields.”

4.1.9. Tubewell Operation and Maintenance Costs

Aside from depreciation, tubewell operation and maintenance costs include four items:

- **Diesel** - Energy for private tubewells is supplied exclusively by diesel since the electricity is not reliable and is available for an average of two hours a day only.
- **Lubricating oil** - Diesel engines, like all internal combustion engines, also consume fair amounts of lubricating oil.
- **Maintenance and parts** - Because most diesel pumps were purchased second hand, they are expensive to maintain. Improper maintenance such as failure to clean and service the pumpset regularly, operating it in a slant position, using adulterated diesel, and improper repair, results in parts being frequently replaced. Farmers complain that original spare parts are not always available and the available spare parts are usually of poor quality.
- **Operator** - Tubewell owners operate their own pumpsets. As will be mentioned in the discussion of the water market, there is a notional charge for operating the well.

Costs of conveying water to the field are not considered here, because costs are generally small except where pipe is used. Costs of conveyance also vary greatly depending upon the location of the fields to be irrigated with respect to the well.

The costs of operating a STW in the study area in 1992 and 1999 are, except for operator costs and depreciation summarized in Table 14. It shows that the average 1999 operation and maintenance cost, not counting operator costs, was Rs 21.43 per hour. Using this figure together with the average discharge of 9.2 liters/second, the average cost of 10,000 liters of water in 1999 was Rs 6.45.

Table 14. Average Operation and Maintenance Costs of Private Tubewells.

<table>
<thead>
<tr>
<th></th>
<th>1992</th>
<th>1999*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Usage (hours/year)</strong></td>
<td>244</td>
<td>244</td>
</tr>
<tr>
<td><strong>Discharge (lps)</strong></td>
<td>9.2</td>
<td>9.2</td>
</tr>
<tr>
<td><strong>Diesel</strong></td>
<td>1938</td>
<td>3026</td>
</tr>
<tr>
<td><strong>Oil</strong></td>
<td>603</td>
<td>942</td>
</tr>
<tr>
<td><strong>Maintenance</strong></td>
<td>807</td>
<td>1260</td>
</tr>
<tr>
<td><strong>Total O&amp;M cost (Rs)</strong></td>
<td>3348</td>
<td>5228</td>
</tr>
<tr>
<td><strong>Average pumping cost (Rs/hr)</strong></td>
<td>13.72</td>
<td>21.43</td>
</tr>
<tr>
<td><strong>Average water cost (Rs/10,000 liters)</strong></td>
<td>4.13</td>
<td>6.45</td>
</tr>
</tbody>
</table>


Maintenance costs are affected by the positioning of the pumpset; slanted pumpsets require more repairs (see Raju et al., 1994). Farmers appear not to know that operation of their pumpsets in a slanted position raises maintenance costs significantly.
4.2. Institutions for Managing Ground Water Use

4.2.1. Policies, Laws, and Regulations

At present, there are no laws or regulations regulating the use of ground water. As in the rest of India, it is presumed that the owner of land has full rights to exploit ground water below that land for any purpose and to any desired extent (Salthe, 1996).

The central government has attempted to convince the states, most recently in 1991, to adopt state laws regulating ground water usage to prevent overdraft and pollution. No state has done so.

The 1993 State Water Policy, prepared by the Second Irrigation Commission, gives priority to the “conjunctive use of surface and ground waters for irrigation” (GOB, 1994: Volume 6, I/44). Also it states “overexploitation of ground water will be prevented by appropriate measures, including legislation” (GOB, 1994: Volume 6, I/45). Surprisingly, despite the above, the 2nd Irrigation Commission made no additional recommendations about regulating ground water use (GOB, 1994).

4.2.2. Local Institutions and Customs

Local concepts of rights to ground water agree with the general principle mentioned above; i.e., that rights to ground water go with ownership of land. As mentioned above, farmers generally own and operate their own farms or, more commonly, take land as sharecroppers. Virtually all wells are on land farmed by the landowners.

Tubewells, like land and pumpsets and other movable property, can be “owned” by an individual person or a recognized group. The owner has virtually complete control over the use of an owned tubewell.

As mentioned in Section 3.2.4, the widely accepted relationships among villagers and farmers are caste, kinship, village, and faction. As will be explained, these relationships, particularly caste and kinship play a part in the management of ground water.

4.2.3. Central Ground Water Board and Authority

Because water is a state subject, the central government had no mandate to regulate the use of ground water. However, the Central Ground Water Board was made responsible for monitoring ground water throughout the country. The Board identified areas in the country that were in danger of overdraft but could take no action. The sole regulatory action based on this work of the Central Ground Water Board is that banks (all regulated nationally) were forbidden to issue loans for installation of wells in “black” or “gray” areas.

In 1997, the Indian Supreme Court issued a judgement mandating the creation of a Central Ground Water Authority with the powers to regulate usage of ground water anywhere in the country. The judgement was passed in response to a public interest suit brought by an environmental group, and in view of the failure of the states to regulate use and pollution of ground water.

The Central Ground Water Board has taken on the functions of the Central Ground Water Authority. However, so far they have only begun to plan their actions. Their first priority is to
tackle the ground water problems of Delhi where both overdraft and pollution are major problems. So far, there is no attempt at regulation in Bihar.

4.2.4. Minor Irrigation Department

A Minister and Secretary head the Bihar Minor Irrigation Department. It has two wings: Minor Irrigation and Tubewells. The Minor Irrigation Wing deals with small-scale surface systems and will not be further discussed. Nor will we go into detail on various special organizations that fall under the Minor Irrigation Department.

4.2.4.1. Tubewell Wing

The Tubewell Wing is headed by an Engineer-in-Chief and has two Chief Engineers: one for North and Central Bihar and one for South Bihar. There are 26 Superintending Engineers, each heading 3-4 divisions. There are 89 divisions, each headed by an Executive Engineer. Other Executive Engineers work in specialized groups, including the Ground Water Directorate. Altogether there are 105 Executive Engineers.

The Tubewell Wing operates about 5500 state tubewells. It is presently involved in attempting to organize farmers to turn these wells over to them. Also it is focusing on upgrading existing public tubewells and installing more public tubewells. Initially, these tubewells were funded from World Bank loans. Now, this scheme is being funded by the National Bank for Agriculture and Rural Development (NABARD).

Although there are some public tubewells in the VBC area, these were explicitly installed where canal water is not available. Therefore, we are not considering them further.

4.2.4.2. Ground Water Directorate

The Ground Water Directorate has following functions:

- Monitoring water levels (in 1600 wells over the whole state)
- Chemical analysis of water quality
- Exploratory drilling
- Prepare survey reports

The Ground Water Directorate monitors groundwater all over the state.

In recent years, The Ground Water Directorate has been using remote sensing data for exploratory drilling. They are looking for fracture locations as places to drill for water in the south using satellite photos.

The Bihar Department of Statistics rather than the Ground Water Directorate carried out the ground water census of 1998. It was funded by the Ministry of Water Resources of the Government of India.
4.2.5. Tubewell Subsidy Programs

The Minor Irrigation Department estimates that there are about 800,000 STWs in the state. However, they also estimate that only about 100,000 of the private tubewells were installed solely with private resources; all the rest were subsidized in some way by government.

Since 1980, various agencies of the Government of India, as a part of poverty alleviation efforts, have subsidized various types of asset creation for income generation. Among other things, subsidies have been granted for tubewells and pumps. Table 15 shows the centrally sponsored subsidy schemes in operation in Bihar during the Seventh five-year Plan (1987-1992). Besides these the Command Area Development Authority provided a subsidy to small and marginal farmers. During the Eighth five-year Plan (1992-97) a total subsidy of Rs.37.5 million was provided for construction of field channels, land leveling and shaping, field drains, groundwater development, and sprinkler and drip irrigation.


<table>
<thead>
<tr>
<th>Name of Scheme</th>
<th>Operating Department</th>
<th>Center: State Funding Ratio</th>
<th>Nature of Scheme</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strengthening Surface Water-Groundwater Organizations</td>
<td>Ministry of Water Resources</td>
<td>50:50</td>
<td>Purchase of machinery and equipment such as rigs, etc.</td>
</tr>
<tr>
<td>Encouraging Irrigation through Sprinkler/Drip Systems, etc.</td>
<td>Ministry of Water Resources</td>
<td>50:50</td>
<td>Subsidy for small, marginal, and SC/ST farmers at rates of 25%, 33.33% and 50% respectively.</td>
</tr>
<tr>
<td>Pilot Scheme for Rectification of Diesel Pumpsets</td>
<td>Ministry of Water Resources</td>
<td>50:50</td>
<td>4400 (all India) irrigation pumpsets are to be rectified to increase efficiency.</td>
</tr>
<tr>
<td>Census of Minor Irrigation Works</td>
<td>Ministry of Water Resources</td>
<td>50:50</td>
<td>Conducting census of minor irrigation works by the States.</td>
</tr>
<tr>
<td>Assistance to Small and Marginal Farmers for Increasing Agricultural Production</td>
<td>Department of Agriculture</td>
<td>50:50</td>
<td>Rs.350,000 per Block per year for minor irrigation works to give subsidies to small, marginal, and tribal farmers at rates of 25%, 33.33% and 50% respectively.</td>
</tr>
<tr>
<td>Oil Seed Production Programme</td>
<td>Department of Agriculture</td>
<td>50:50</td>
<td>Subsidy for installation of sprinklers at the rate of 50% to small and marginal farmers and 25% to other farmers.</td>
</tr>
<tr>
<td>Integrated Rural Development Programme</td>
<td>Department of Rural Development</td>
<td>50:50</td>
<td>Subsidy for minor irrigation works to small, marginal and tribal farmers at the rate of 25%, 33.33% and 50% respectively.</td>
</tr>
<tr>
<td>Jawahar Rozgar Yojana</td>
<td>Department of Rural Development</td>
<td>80:20</td>
<td>Support minor irrigation works. Irrigation wells provided free of cost to small and marginal farmers belonging to SC/ST.</td>
</tr>
<tr>
<td>Drought Prone Area Programme (DPAP)</td>
<td>Department of Rural Development</td>
<td>50:50</td>
<td>Development of water resources in drought prone areas.</td>
</tr>
</tbody>
</table>

Source: (GOI), 1993
The most widespread subsidy schemes have been those administered by Block Development Offices. Each year a new target for subsidies has been fixed based on the resources made available by the government. Hence the number of tubewells and pumpsets subsidized under these schemes has varied every year. Table 16 shows that under the 1992 programs eligibility for subsidies was based on caste or size of landholding. The present subsidy program officially began in 1992-93. However, according to the Secretary of Minor Irrigation, the program is suffering from decreasing state funding. During the first year, the state government allocated Rs 150 million but last year they allocated only Rs 5 million which might be enough for 15,000 STWs. This program provides pipes only. Some districts are using their own development funds to subsidize purchase of pumpsets.


<table>
<thead>
<tr>
<th>Item</th>
<th>Eligibility</th>
<th>Subsidy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tubewell</td>
<td>Scheduled caste/tribe</td>
<td>100 %</td>
</tr>
<tr>
<td></td>
<td>Marginal farmers (0 to 2.5 acres)</td>
<td>90 %</td>
</tr>
<tr>
<td></td>
<td>Small farmers (2.5 to 5.00 acres)</td>
<td>70 %</td>
</tr>
<tr>
<td>Diesel pumpsets</td>
<td>Scheduled caste/tribe</td>
<td>100 %</td>
</tr>
<tr>
<td></td>
<td>Marginal farmers (0 to 2.5 acres)</td>
<td>33 %</td>
</tr>
<tr>
<td></td>
<td>Small farmers (2.5 to 5.00 acres)</td>
<td>25 %</td>
</tr>
</tbody>
</table>


In addition to the main program, other subsidies have been granted at various times. Diesel pumpsets were distributed by commercial banks to marginal farmers during 1976, 1984-86 and 1988-89 and to small farmers during 1981-82 and 1988-89. Beginning in 1988-90, a subsidy of Rs 3000 per well was provided to small and marginal farmers through the Framework Action Plan for Foodgrain Production, a special program of the Government of India. Funds from an Integrated Rural Development Programme were used for giving subsidies for pumpsets to small and marginal farmers below the poverty line.

Under the main subsidy scheme, the Block Development Office informs farmers of the availability of the scheme through its official notice board; the information spreads through word of mouth. Those who would like to get a subsidy send written applications through their Village Council leader. The Block Development Office selects the persons to be granted subsidies to the number of units sanctioned by the government. The farmers complained that "recommendations by suitable persons are important in this process." The amounts of pipe and drilling costs covered have varied over the years.

During the initial years of the scheme, farmers got the full quota of pipe length irrespective of proposed depth of well. Some farmers got up to 140 feet of pipe out of which they could sell as much as 50 percent. From 1985, allotted pipe length was reduced to 80 feet, irrespective of the length applied for. Normally, farmers apply for more than the allotment in hopes of getting at least 80 feet. According to the scheme, a Supervisor from the Block Development Office is supposed to visit the site and certify the length of pipe actually installed. However, the Supervisor usually does not visit the installation site or he visits after installation is completed. In either case, he certifies the length which farmer quotes.

In our 1992-93 study, 20 of the 51 individual tubewell owners in the study area had received surplus pipe. The surplus pipe was generally sold outside of the village after a few months or even after two years. In Madan Chapra, filter pipe, as well as blind pipe, is used for some tubewells. But
filter pipes are not provided under the subsidy scheme. Thus they can sell the blind pipe that has been replaced with the filter pipe.

Pumpsets are also subsidized, but most farmers have preferred to purchase secondhand pumpsets. At some times, scheduled caste farmers got a 100% subsidy for pumpsets. For all other farmers, secondhand pumpsets are cheaper than the subsidized pumpsets. Under the rules of the subsidy scheme, only new pumpsets can be purchased. Bank loans have also been available to some for the purchase of new pumpsets. Of the 1992-93 sample, 30 of 40 individual pumpset owners purchased used pumpsets, either from those who got them under the 100 percent subsidy schemes or from those residing outside the Block. Reported distances ranged from 19 km to 52 km. Purchase from a distance is done to avoid problems with the Block Development Office, which administers not only the subsidy schemes, but also all other development activities in the Block. It is worth noting that ten pumpset owners who got theirs under a subsidy scheme or with a bank loan have retained rather than sold their pumpsets.

Buyers of secondhand pumpsets generally prefer those from four to five years old. In 1992-93, such pumpsets were sold for between Rs 3496 and to Rs 3937 each, while new ones cost between Rs 5063 and Rs 5504. For our sample pumpset owners the average difference in price between new and used pumpsets was Rs 2904; this is greater than the Rs 1800 or so available as a subsidy to many of the farmers.

The Government of India is formulating a new assistance scheme for the eastern region. One feature is that it will provide pumpsets to be shared among groups of farmers with borings.

4.2 6. Group Tubewells: VASFA and Similar Organizations

4.2.6.1. Group Tubewells

Group tubewells, jointly owned and operated by several farmers, have been and are being promoted as a more effective way for poor farmers to exploit ground water. Group tubewells have been promoted by non-government organizations (NGOs) and, occasionally by government organizations. In some cases, farmers have created group tubewells on their own, particularly those who have learned of such things through observation of group tubewells promoted by an NGO. Tubewell groups may or may not have legal status. A study of group wells (Nagabrahman and Raju, 1987) in five different Indian states showed that the viability of the group depends upon the size and homogeneity of the group.

In the VBC area, two kinds of group tubewells are found: VASFA tubewells and local group tubewells. VASFA tubewells are group tubewells installed and managed by the Vaishali Area Small Farmers Association (VASFA). Local group tubewells are those created by local farmers on their own initiative.

During 1972-78, four VASFA group tubewells were installed in Shampur Minor area. There is also one local group tubewell in the same area. Neither kind of group tubewell is found under the other two 1992-93-sample minors.
4.2.6.2. **VASFA**

The Vaishali Area Small Farmers Association (VASFA) is a farmer's cooperative association headquartered in the town of Vaishali and serving members in the area surrounding Vaishali.

VASFA was founded in the 1972 under the guidance of B.D. Diwan with help from an NGO then called Peoples' Action for Development India. This NGO is now known as Council for Application of People's Action in Rural Technology (CAPART). Initially, VASFA received a grant of Rs 400,000 from the Government of Norway. Of this, half has been used as a revolving fund for development works carried out by VASFA, particularly for construction of tubewells. The other half of the grant has been kept in the loaning bank (Central Bank of India) as a security against loans. CAPART now is a semi-government agency under the Ministry of Rural Development of the Government of India and the Central Bank of India.

The following are the main objectives of VASFA:

1. To provide agricultural training and impart knowledge of modern agriculture to farmers, particularly small farmers.
2. To organize different kinds of activities in order to improve the economic and social conditions of small farmers.
3. To attract farmers to industries based on agricultural produce.
4. To arrange loans for community tubewells, agricultural machinery, warehouses, and pesticide sprayers.
5. To act as a link between CAPART, the Vaishali Sangh, the Agricultural Finance Corporation and other organizations and institutions which are working for the development of agriculture.
6. To organize farmers into special regional working groups.
7. To obtain funds from persons, associations, trusts, and national and international institutions for the development of VASFA.

An executive committee consisting of a President and 3 Vice-Presidents manages VASFA, each representing one of the three zones where VASFA works. All members elect these officers for terms of one year and three years respectively. A Treasurer representing CAPART and a General Secretary are nominated jointly by CAPART and VASFA for terms of 6 years each.

Government support for VASFA is coordinated through a joint committee of government officials and farmers. The Commissioner of the Tirhut Division serves as President of the committee. The President of VASFA serves as Vice-President while the General Secretary of VASFA acts as the Secretary of the committee. The members of this committee are Deputy Commissioners of Vaishali and Muzaffarpur Districts, senior officials of the government, and three progressive farmers of the area. These farmers may or may not be the members of VASFA.

4.2.6.3. **VASFA Tubewell Groups**

Although VASFA uses several means to improve the lives of its members through improving their agricultural production, establishment of group tubewells is basic to their strategy.

---

3 Most of the information about VASFA is based on its annual reports, and discussion with VASFA officers. Additional information is derived from CWRS (1993). For more information, see Pant and Rai (1985).
VASFA has actively promoted the establishment of group tubewells. The procedure involved first the selection of a village having many small and marginal farmers by the General Secretary of VASFA with the help of block officials. A VASFA organizer then identified one or more sets of farmers having small and contiguous holdings within an area of 20 to 40 acres of land. He then would work to persuade them of the benefits of a jointly owned tubewell. Once the group was convinced and had agreed to follow VASFA’s rules, VASFA would provide help with bank financing and technical assistance to install and equip the tubewell. However, the tubewell is owned and operated by the group rather than VASFA. Members have to repay the bank loan; the cost is divided among the group members in proportion to their landholdings within the command of the tubewell. These tubewell groups are called "Krishak Dal" and are the basic constituent groups of VASFA.

VASFA provides other assistance to tubewell groups, including the use of power threshers, sprayers, and other agricultural equipment, other needed materials, and marketing facilities. Also, those farmers who cannot meet their household requirements even after a good crop on account of the small size of their holdings are provided assistance to establish other income producing activities in animal husbandry, fisheries, poultry, household industry, etc.

Tubewell group sizes vary from 15 to 45 farmers. Generally farmers having land over 5 acres are not included. Every attempt is made to see that the holdings of group members are contiguous so that they can be efficiently commanded by the tubewell. Group members are also made aware of the responsibilities of entering into an agreement for obtaining a bank loan for the installation of tubewell and for other purposes.

The process of installing and equipping a VASFA tubewell was as follows:

- Members paid Rs 5 each as an admission fee and Rs 3 as an annual membership fee to VASFA.
- For the tubewell site, one member had to donate 0.02 acres of land to VASFA.
- Each member submitted a copy of the record of his landownership and signed an agreement to follow the rules of VASFA.
- The tubewell group elected a group leader.
- Once the group was established, an application for a loan was submitted to the bank. The bank provided the funds from VASFA’s revolving fund.
- The funds were used for drilling the well and installing the pipes, construction of the tubewell cabin, installation of the pumpset, energization, and construction of field channels.
- At this stage the members entered into direct agreement with the Bank according to which the borrowed amount was treated as a loan to individual farmers.

According to the constitution of VASFA, the repayment of the loan was to commence after three years of its sanction. Each farmer was required to repay his loan with interest over five years in biannual installments. Repayment was left entirely to the members.

VASFA presently has 36 tubewell groups. The most recent was started in 1982. Some of the tubewells have completed their expected life span of 20 years; many are due for replacements and relocation. In 1995-96, eight defunct VASFA tubewells were relocated with all new equipment purchased with a CAPART loan and VASFA’s assistance. Relocating and refurbishment costs about Rs10, 000 that group members find difficult to mobilize. Not all groups are demanding
rehabilitation since many of them have either their own or access to nearby privately owned tubewells.

4.2.6.4. **VASFA Imitators**

VASFA was founded in 1972, the first organization of this type in the area. Over a period of time group tubewells attracted more farmers. In addition, with assistance from CAPART, another 17 small farmer associations similar to VASFA were formed in North Bihar. Together, the 18 organizations have around 150 group tubewells. VASFA is the largest as well as the oldest such organization.

There is little demand for group tubewells now (1999). A former VASFA Vice-Chairman told us that the current demand is for individual tubewells rather than for group tubewells; individuals like to have the water source under their direct control or nearby. He also noted that some members installed their own tubewells, partly because of the availability of government subsidies, and lost interest in VASFA affairs. This increased the density of tubewells in the area and for both landowners and sharecroppers, nearby tubewells came into existence reducing dependence on group tubewells. Currently the group tubewells sell water at Rs 25-30 per hour to their members and others, while private tubewells sell water at Rs 30-35 per hour; but the private tubewells are generally closer and some private well owners provide conveyance pipes. Also, there is more flexibility in timing.

These small farmer associations now focus on other activities, including gobar-gas plants, sanitation and latrine construction, and hand pumps for drinking water.

4.2.6.5. **Local Group Tubewells**

In some cases, farmers familiar with group tubewells supported through VASFA or similar groups tried to create their own local tubewell groups. We have no idea how many such tubewell groups exist. There was only one in the 1992-93 sample areas.

One of the four VASFA group tubewells located in Haharo village under Shampur Minor was dominated by upper caste Rajputs. The group also had five Scheduled Caste members. These five farmers felt that the Rajputs did not allow them to take part in group decisions and discriminated against them in water distribution. As a result, in 1973, all five Scheduled Caste members walked out of the VASFA group. Since they had contiguous landholdings, they decided to organize their own group tubewell. They purchased their tubewell and diesel pumpset with the help of a bank loan taken on joint responsibility and fully repaid the loan within 3 years.

4.2.7. **The Water Market**

4.2.7.1. **Basic Nature of the Water Market**

Water sales have taken place in the study area for a very long time. Water lifted from open wells or the rivers used to be provided in return for a portion of the crop. Today, however, open wells have been replaced by tubewells and diesel pumps because of greater efficiency and lower cost have replaced manual river lifting mechanisms.

In the local water market, water itself is neither priced nor sold; pumping services are sold (cf Saleth, 1996). Thus canal water does not enter the market. The following shows this:
• Farmers say that they do not charge for water as such.
• The price is justified by reference to the costs of pumping, not to the productive or other value of the water.
• The price is an hourly price; that is the buyer buys pumping time not a quantity of water.
• The pumping price practices are the same for both ground water and water lifted from rivers.

There is no essential difference between ground water and river water in the eyes of buyers and sellers. However, the market for the river lift pumping is, naturally, limited to areas near rivers. Since the great majority of sellers in the sample area are tubewell owners, the following discussion focuses specifically on them. However, all the basic principles also apply to river lift pump owners.

4.2.7.2. Sellers and Buyers

For all well owners the primary motive for installing a tubewell or acquiring a pump is to obtain a sure supply of irrigation water for their own crops. However, all owners considered possible sales to others when considering investing in a tubewell; all well owners consider themselves potential suppliers of irrigation water to others. Owners expect earnings from pumping to meet at least part of their operations and maintenance costs; they hope to irrigate their own lands free of cost. Thus, well owners always consider potential buyers when locating their tubewells. Locations near the edge of fields are preferred. Also they consider which people might be potential buyers, including relatives and caste mates.

In contrast to well owners, some river lift pump owners explicitly view sales of pumping services as an important reason for acquisition of their pumps. When discussing maintenance, one of the river lift pump owners said, "I have invested money on this (pump) on my own initiative. So I take care of it as if it were a milking cow. Regular cleaning and proper handling is essential. My pump gives a good discharge (11 l/sec) and I sell water whenever buyers want - early morning or late evening which are cool hours. I do not dictate my terms for sale timings. So, buyers definitely opt for my pump and I earn good money by selling water."

Buyers tend to be farmers with smaller holdings located near to the tubewell; they often have some kind of ongoing relationship with the seller. However, virtually all farmers can purchase pumping services if they wish to. Any farmer who does not own his own functioning tubewell is a potential buyer of water. Even those with access to canal water may need to buy water at times because canal supplies are erratic. Most buyers have small or marginal landholdings. Many buyers are relatives of the seller; others are sharecroppers who do not want to invest in a well. Demand from buyers varies over space and time depending upon the crop(s) planted, the weather conditions, access to other water sources, particularly canal water, and the cost of buying water relative to the value of the crop.

In our 1992-93 sample of private tubewell owners, 37 out of 51 sold water to others. Five of these did not have pumps functioning so they rented pumps to irrigate their own fields and sell water at the same time. Also all four VASFA groups sold water.

Table 17 gives data on the 37 private water sellers and their buyers. This table shows two points:

• Water selling becomes more important the further down the VBC one goes.
• Sellers irrigate significantly more land than do buyers.
Table 17. Private Tubewell Water Sellers and Buyers (1992-93).

<table>
<thead>
<tr>
<th></th>
<th>Chakwa</th>
<th>Madan Chapra</th>
<th>Shampur</th>
<th>Total Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Numbers of farmers:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Sellers</td>
<td>5</td>
<td>15</td>
<td>17</td>
<td>37</td>
</tr>
<tr>
<td>- Buyers</td>
<td>25</td>
<td>79</td>
<td>82</td>
<td>186</td>
</tr>
<tr>
<td>Average irrigated area (ha):</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Sellers</td>
<td>0.47</td>
<td>0.88</td>
<td>0.83</td>
<td>0.80</td>
</tr>
<tr>
<td>- Buyers</td>
<td>0.24</td>
<td>0.24</td>
<td>0.19</td>
<td>0.19</td>
</tr>
</tbody>
</table>

Sellers generally have larger landholdings than buyers. Tubewell owners invest in tubewells primarily to serve their own fields; only those with larger holdings find it worthwhile.

Table 18 gives information on buyers and sellers for all four of the water sources from which water could enter the water market in the three sample minor canal areas. This table shows that the tubewell group members have, on the average, considerably smaller holdings than do the private tubewell owners. The shared investment costs of group tubewells make it reasonable for these farmers to invest in a tubewell.

Table 18. Comparison of Sample Buyers and Sellers by Source, 1992-93.

<table>
<thead>
<tr>
<th></th>
<th>Private Tubewell</th>
<th>Local Group</th>
<th>VASFA Group</th>
<th>River Lift</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of users:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Sellers/members</td>
<td>37</td>
<td>5</td>
<td>60</td>
<td>5</td>
</tr>
<tr>
<td>- Buyers</td>
<td>186</td>
<td>-</td>
<td>36</td>
<td>75</td>
</tr>
<tr>
<td>Average no. of users per well:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Owners/members</td>
<td>1</td>
<td>5</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>- Buyers</td>
<td>5</td>
<td>-</td>
<td>9</td>
<td>15</td>
</tr>
<tr>
<td>Average area irrigated (ha):</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- per Seller/member</td>
<td>0.80</td>
<td>0.16</td>
<td>0.28</td>
<td>na</td>
</tr>
<tr>
<td>- per Buyer</td>
<td>0.19</td>
<td>-</td>
<td>0.20</td>
<td>na</td>
</tr>
</tbody>
</table>

Generally, a buyer buys pumping services from one seller only. Buying from one seller allows the development of longer term relationships and also minimizes costs and difficulties of changing water conveyance facilities - mostly unlined field channels - whenever the buyer buys from a different seller. To minimize conveyance costs and conveyance losses, most, but not all, buyers buy from the nearest seller.

4.2.7.3. Cartel Prices

Sellers in the study area, including managers of group tubewells and owners of river lift pumps, have formed informal cartels to set prices. The pumping price is fixed at a more or less uniform rate over the local area through informal meetings and discussions. Informal meetings among tubewell owners to discuss the pumping price are held as needed, generally when there is an increase in diesel, oil or spare parts prices. Meetings are usually held in a mutually convenient place, sometimes under a tree. No records or minutes are kept. Since there is no compulsion to attend, not all tubewell owners come to these meetings. Communication among owners is by word of mouth.
Owners generally have increased pumping prices in response to diesel and oil price increases. However, the relationship between diesel price and pumping price is not rigid. Prior to 1992, diesel prices increased faster than pumping prices. Since then it appears that the cartel prices have increased faster than the diesel prices (cf. Shah and Ballabh, 1997).

Although pumping prices had varied among the three minors in the past (partly in response to variations in diesel prices), in 1992 the cartel pumping price was Rs 20 per hour for all three minors. In 1999, the cartel pumping price was Rs 50 per hour in Shampur Minor and Rs 40 per hour in Madan Chapra Minor.

Pumping costs in 1992 averaged about Rs 12 per hour and in 1999 averaged around Rs 22 per hour excluding capital and operator's labor costs. The difference between pumping price and pumping cost is viewed as a return to investment and to the labor of operation.

4.2.7.4. Transacting Sales

There are two standard ways of handling the sale of pumping services, by paying in cash at the time of the sale or by providing diesel and paying the balance in cash at a later time. In either case, the buyer is supposed to pay the full rate charged by the seller. Group tubewells, however, generally require cash payment before the water is pumped.

Private sellers have difficulties in collecting fees; in many cases they are not able to collect the full fees. A seller's ability to collect fees depends greatly on the social and economic relationships between himself and the buyer. Important factors include kinship, caste, and economic power. Some sellers move aggressively to collect fees; aggressiveness seems to be rewarded with some degree of success.

Difficulties in collecting fees arise with regard to both when payments are made and how much is paid. We will deal with how and when payments are made first.

In 1993, of the 186 buyers from the 37 sellers of private tubewell services, 41% had not paid their 1991-92 debts in full a year later:

- No family member paid cash at the time of service; and after a year fully 70% of family members had not completed payments.
- Only one-third of same caste buyers paid their fees at the time of service. 82% of those who provided diesel had not fully paid at the end of a year.
- In contrast, 87% of lower caste buyers paid immediately in full. Even among those who provided diesel, 60% had paid up fully; fully 50% had paid by the end of the crop season.
- Higher caste buyers tended to provide diesel rather than pay immediately in cash. None of those who provided diesel had paid at the end of a year.

Taking these delays into account, we can estimate the amounts actually paid. In 1992, all except two of the sample sellers stated that their selling rate was Rs 20 per hour. One of the two exceptions charged Rs 16 per hour and the other Rs 18 per hour; they had three and nine buyers respectively.

Significant numbers of buyers pay less than the full rate. In 1992, fully 46% of buyers from private tubewell owners and 33% of buyers from river lift pump owners paid less than the full rate.
generally by delaying payment, particularly if they provide diesel. Sellers generally collect something, even if the buyer provides the fuel. In fact, the 1992 minimum collection (including fuel cost) of Rs 12 per hour was close to the average operating costs. However, note the following:

- The majority of family members, both immediate family and those in other households, paid less than the full rate. In the case of private tubewells, only 14% of family members paid the full rate.
- Fully 61% of same caste members paid less than the full rate to private tubewell owners, although 100% paid the full rate to river lift pump owners.
- Although they may have to be aggressive to do so, sellers were able to collect the full rate from the great majority of lower caste buyers - 94% for both private tubewells and river lift pumps.
- The majority of higher caste buyers - 56% in the case of private tubewells and 80% in the case of river lift pumps - paid less than the full rate.

Even the two well owners who sold pumping services at less than the cartel rate in 1992 had trouble collecting. One, a farmer in Shampur Minor, sold at Rs 16 per hour to three buyers. However, one of them, an higher caste man, managed to pay only Rs 15.30 per hour over the season. The other seller, also in Shampur Minor, sold at Rs 18 per hour and had nine buyers. Six of these belonged to the seller's caste and paid Rs 15-16 per hour. However, the other three buyers belonged to a lower caste and paid the full rate.

The same difficulties existed in 1999. One tubewell owner in Madan Chapra told us that although he sets the rate at Rs 40 per hour, he is lucky to collect Rs 28 per hour. Many of those who provide diesel pay him nothing; from some - presumably lower caste - he may get Rs 5 per hour to cover costs other than diesel.

4.2.8. Private Service Organizations

It should be noted that there are numerous private persons who provide services to support tubewells, including mistries who drill wheels, dealers in pipe and pumps sets and in tools and parts needed to maintain the tubewells, the mechanics who repair malfunctioning pumps sets, and the dealers in diesel and oil.

Although well owners often complained about the quality of parts and services, these are relatively easily available in the area.

4.3. Methods for Managing Ground Water Use

As discussed in detail in Section 5, ground water is used for irrigation in the VBC Command only when other sources - rainfall or canal water - are not available. Therefore, in this section, we discuss only how pumps are operated.

4.3.1. Management of Private Tubewells

Private tubewell owners operate their own wells, either when they need water for their own crops or at the request of a water buyer. Operation involves moving the pumpset to the boring, connecting it, filling the diesel (and changing the oil if needed), and running the pump for the desired period. Even if a water buyer supplies diesel, the tubewell owner operates the pumpset.
If a tubewell owner does not own his own pumpset, he can rent one. Pumpset rental costs in 1992 were low - about Rs 5-8 per hour - just enough to cover maintenance. Of course, a tubewell owner would be able to rent a pumpset only from someone with whom he had a close relationship since the pumpset rental market is not well developed.

Pumpset maintenance is handled by hiring a mechanic as needed or by the pumpset owner buying the parts and repairing the pumpset himself.

Since the use of the pumpset is controlled directly by the tubewell owner, conflicts are non-existent.

4.3.2. Management of Group Tubewells

4.3.2.1. VASFA Group Tubewells

Each group leader is responsible for the management of the tubewell with the help of VASFA officials. Tubewell management includes allocation of pumping time, well operation, timely maintenance and repair to the tubewell and field channels, maintenance of irrigation records, and maintenance of financial accounts.

For allocation, time is generally allotted to the members as per the proportion of their land in the tubewell command. Sometimes it is allocated by mutual agreement. Non-members can purchase pumping time. However, the priorities are: 1) members' land in the command, 2) non-members' land in the command, and 3) lands outside the command.

Tubewell operation is generally carried out by the group leader or by one of his family members. The operator is required to maintain records of pumping time taken by each individual user. Usually operators maintain the records on a piece of paper or in a notebook rather than in proper record books. This practice results in various problems in maintenance and preservation of the records.

The group leader arranges maintenance of the tubewell. VASFA provides trained mechanics and parts. Members as per their share in the tubewell command share expenses incurred on maintenance and repair. For the maintenance of field channels, two systems are followed. In one, members clean and maintain the field channels up to their plots only. In the other, members work as a group to maintain the channels.

Conflicts are rare. When they occur, the prevalent and most effective mode of conflict resolution is a group meeting. VASFA officials sometimes attend these meetings. Cases were found where recalcitrant members were threatened with termination of their membership, but no terminations have been reported.

The group leader with the consent of his group members fixes pumping charges. Water charges of electrical and diesel operated tubewells are different and charges to non-members are much higher than charges to members. All four VASFA tubewells in the study area have diesel pumps. The 1992 pumping charges were fixed at Rs 14 per hour for members and Rs 20 per hour for non-members. The latter is the cartel price in the water market. Members pay their pumping charges at the time of sale of the crop but non-members are generally required to pay immediately after taking water. This system is not rigid; sometimes non-members pay on a monthly basis. The group leader collects the pumping charges and pays the electricity bills or purchases diesel.
The group leader maintains income and expenditure accounts; he is required to produce these records at group meetings. Profits from tubewell operations, if any, are distributed among the members. Similarly, members must pay their shares of the deficits.

4.3.2.2. The Sample Local Group Tubewell

A senior member of the group looks after overall operation and maintenance. All the five members equally share expenditure incurred on repairs and maintenance. Water is usually pumped on a first come first served basis. However, during a crisis they establish a pumping schedule by consensus. During the last 20 years, members say they have not had problems in water distribution.

Each member has to arrange diesel on his own for the required duration of pump operation and he operates the pumpset for himself. If any diesel is left in the tank at the end of pumping, the member can take it back. More often he sells it to the next user at the market rate.
5. CONJUNCTIVE MANAGEMENT IN THE VBC COMMAND

Farmers in the VBC Command to supplement rainfall use both surface and ground water. However, as we have shown, canal water is available only in part of the VBC command and its availability is unpredictable. Water lifted from other drains and the Baya River is important to farmers in some areas. More importantly, good quality ground water is available at shallow depths everywhere and thus is used to supplement or replace canal water when rainfall is insufficient.

The locus of conjunctive management is the individual farm. Only individual farmers have some control over which source of water they use. The key question then is how do farmers decide what source of water to use for irrigation?

5.1. SOURCES OF IRRIGATION WATER

To understand how farmers use the different sources of irrigation water, we traced the sources of irrigation for the individual fields in the study area by questioning farmers. We asked farmers about four crop seasons: kharif 1991, Rabi 1991-92, summer 1992, and kharif 1992.

We found that farmers use the following terms for sources of water:

- Rain: where for a particular irrigation, a field has been entirely watered by timely rainfall.
- Canal: where a field has been irrigated entirely by canal water for a particular irrigation.
- Tubewell: where a field has been irrigated entirely by tubewell water for a particular irrigation. For this discussion no distinction is made between irrigation from the farmer’s own tubewell or from someone else’s tubewell.
- Canal and Rain: where for a particular irrigation, a field has been partly watered by timely rainfall and partly irrigated by canal water.
- Canal and Tubewell: where for a particular irrigation, a field has been partly irrigated by canal water, and partly with water from a tubewell.

Less important sources include:

- Dugwells
- Hand pumps installed on a tubewell
- Treadle pumps installed on a tubewell
- Flooded fields: i.e. fields filled with rain water which remains over an extended period.

In addition to fields irrigated by these methods, fields with unirrigated crops and fallow fields were also identified.

5.1.1. Sources of Water in Kharif

Paddy is by far the most important crop during kharif, in part because of the heavy rainfall in most years. Since paddy is the main food crop, farmers try to ensure good yields. Farmers in the study area overwhelmingly cultivate a long age paddy variety, known locally as Aghani paddy. They generally sow the seedbeds in June and harvest in November, unless delayed by lack of water at the beginning of the season.
During kharif season, paddy cultivators mainly use four sources of water: rain, canal, tubewell, and the combination of rain and canal. Tables 19, 20, and 21 show how the individual fields were watered in the three sample minors during kharif 1991. Since the farmers describe plant water needs in terms of 4 irrigations, we have identified the sources of water for each of the four essential irrigations. In these tables, "unirrigated" refers to cultivated fields that contain perennial or other crops that generally do not require human intervention for water. Kharif 1991 was considered a low rainfall season.

5.1.1.1. Chakwa Minor

As shown in Table 19, in Chakwa Minor the first irrigation depended largely upon rainfall. This first irrigation is for establishing the crop in the field and is very important. Canal irrigation at the beginning of the season is quite unreliable because farmers further up the Gandak System use the canal water to establish their crops. Hence farmers depend upon rainfall - generally delaying sowing until the rains come - or tubewells.


<table>
<thead>
<tr>
<th>Water Source</th>
<th>No. of Fields</th>
<th>Area (acres)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Rain</td>
<td>83</td>
<td>88</td>
</tr>
<tr>
<td>Canal</td>
<td>3</td>
<td>16</td>
</tr>
<tr>
<td>Tubewell</td>
<td>56</td>
<td>48</td>
</tr>
<tr>
<td>Canal+Rain</td>
<td>14</td>
<td>4</td>
</tr>
<tr>
<td>Other</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Unirrigated</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Fallow</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Totals</td>
<td>164</td>
<td>164</td>
</tr>
</tbody>
</table>

For the second irrigation in kharif 1991, the pattern was similar to that of the first irrigation. For the third irrigation, however, tubewell use dropped greatly as canal use rose. Canal use rose to a peak for the fourth irrigation. This change occurred because canal water became available late in the season when farmers further up the Gandak System harvested their crops. Overall, farmers in Chakwa Minor plant and harvest 2-3 weeks later than farmers further up the system so that they get some canal water.

5.1.1.2. Madan Chapra Minor

Table 20 shows the kharif 1991 pattern for Madan Chapra Minor. One feature immediately visible is that fields are smaller in Madan Chapra Minor than in Chakwa Minor or in Shampur Minor. Also tubewell water was used only for the first irrigation, rather than for both and first and second irrigations as in Chakwa Minor.

<table>
<thead>
<tr>
<th>Water Source</th>
<th>No. of Fields</th>
<th>Area (acres)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 2 3 4</td>
<td>1 2 3 4</td>
</tr>
<tr>
<td>Rain</td>
<td>321 50 50 111</td>
<td>43.1 11.0 11.1</td>
</tr>
<tr>
<td>Canal</td>
<td>51 14 1 350</td>
<td>8.9 1.6 0.1 46.9</td>
</tr>
<tr>
<td>Tubewell</td>
<td>41 - - -</td>
<td>8.7 - - -</td>
</tr>
<tr>
<td>Canal+Rain</td>
<td>2 350 363 7</td>
<td>0.3 48.2 49.7 1.5</td>
</tr>
<tr>
<td>Other*</td>
<td>2 2 - -</td>
<td>0.6 0.6 - -</td>
</tr>
<tr>
<td>Unirrigated</td>
<td>21 22 24 81</td>
<td>1.9 2.1 2.6 15.1</td>
</tr>
<tr>
<td>Fallow</td>
<td>- - - -</td>
<td>- - - -</td>
</tr>
<tr>
<td>Totals</td>
<td>438 438 438 438</td>
<td>63.5 63.5 63.5 63.5</td>
</tr>
</tbody>
</table>

* This includes two treadle pumps.

Compared to Chakwa Minor, there was greater use of canal water in Madan Chapra Minor after the first irrigation. During the second and subsequent irrigations, Madan Chapra canal water users get together and try to assure water delivery to the minor. Farmers said, "Whenever there is a problem in canal water flow, some of us, usually youths, get together and argue with upper reach villagers. We also fight sometimes, and bring water to our village. In fact, we have to monitor the water both during day and night for two days at least."

5.1.1.3. Shampur Minor

In Shampur Minor, as shown in Table 21, the pattern of use during kharif 1991 was similar to the pattern in the other two minors during the same season. The exceptions were: a) Shampur Minor farmers depended much less upon canal water than did Madan Chapra farmers, and b) a very large number of fields in Shampur Minor are planted with unirrigated crops. Shampur farmers consider both rainfall and canal water very unreliable; tubewell water is considered costly, particularly for water loving paddy. Hence there has been a massive shift to crops that do not depend upon irrigation. Overall, the area planted with paddy is relatively small.


<table>
<thead>
<tr>
<th>Water Source</th>
<th>No. of Fields</th>
<th>Area (acres)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 2 3 4</td>
<td>1 2 3 4</td>
</tr>
<tr>
<td>Rain</td>
<td>69 31 48 3</td>
<td>15.4 7.1 10.4 0.4</td>
</tr>
<tr>
<td>Canal</td>
<td>16 9 11 38</td>
<td>3.3 2.3 2.7 8.7</td>
</tr>
<tr>
<td>Tubewell</td>
<td>1 2 - -</td>
<td>0.2 0.3 - -</td>
</tr>
<tr>
<td>Canal+Rain</td>
<td>3 20 14 5</td>
<td>0.6 4.4 2.8 1.0</td>
</tr>
<tr>
<td>Other*</td>
<td>- - 1 1</td>
<td>- - 0.1 0.2</td>
</tr>
<tr>
<td>Unirrigated</td>
<td>111 138 126 153</td>
<td>32.7 38.1 36.2 41.9</td>
</tr>
<tr>
<td>Fallow</td>
<td>- - - -</td>
<td>- - - -</td>
</tr>
<tr>
<td>Totals</td>
<td>200 200 200 200</td>
<td>52.2 52.2 52.2 52.2</td>
</tr>
</tbody>
</table>

* This includes one case of canal plus dugwell and one case of canal plus tubewell.
5.1.1.4. Observations on Kharif Sources of Water

Overall, the following observations can be made about kharif irrigation in the sample areas:

- During kharif season more farmers depend upon rainfall than upon any other source of water, even though paddy is the dominant crop.
- Because canal water is not available during the early part of the season when upstream farmers are establishing their crops, farmers in the study area often delay sowing and transplanting while waiting for heavy rains. This means that their schedule is 2-3 weeks later than upstream farmers.
- The second most important source of water during kharif is canal water, particularly during the fourth irrigation. Canal water is important for the fourth irrigation because rainfall has dropped during that period. More importantly, canal water is available late in the season because upstream users no longer need it, having begun drying and harvesting their paddy crop.
- Dependence upon groundwater is low during kharif. Some farmers use tubewells for the first irrigation to establish their crops. Only the Chakwa Minor were farmers willing to use tubewells later in the season and that only for the second irrigation.

5.1.2. Sources of Water in Rabi

The main crop in Rabi season is wheat. In the study area, wheat is sown after the paddy harvest in December. Most fields remain moist even up to the middle of December. Ideally wheat is sown by the end of November. As pointed out earlier, farmers feel that wheat should have four irrigations but generally provide fewer, often only two irrigations. This is particularly true for wheat sown late, sometimes as late as early January because of delays in paddy cultivation.

Tables 22, 23, and 24 show the sources of water used by farmers in the sample minors for rabi 1991-92. For wheat cultivation, farmers mainly use three sources of water: rainfall, canal water, and tubewell water.

5.1.2.1. Chakwa Minor

The pattern of water source use in Chakwa Minor during rabi 1991/92 is shown in Table 22. It shows that:

a) a number of fields were left fallow (about 18%)
b) an equal number were flooded during the rainy season - these were planted with a special paddy variety
c) a similar number of fields (around 28%) depended upon rainfall and tubewells for the first two irrigations
d) farmers did not use canal water to any significant extent until the last two irrigations, and
e) during the last irrigation, farmers used canal water in place of tubewell water.
Table 22. Chakwa Minor Sources of Water for Rabi 1991/92.

<table>
<thead>
<tr>
<th>Water Source</th>
<th>No of Fields</th>
<th>Area (acres)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Rain</td>
<td>45</td>
<td>51</td>
</tr>
<tr>
<td>Canal</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Tubewell</td>
<td>50</td>
<td>41</td>
</tr>
<tr>
<td>Canal+Rain</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Other*</td>
<td>29</td>
<td>29</td>
</tr>
<tr>
<td>Unirrigated</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>Fallow</td>
<td>29</td>
<td>29</td>
</tr>
<tr>
<td>Totals</td>
<td>164</td>
<td>164</td>
</tr>
</tbody>
</table>

* All of these fields are flooded fields.

A trend of decreasing use of tubewells can be seen throughout the season. During the fourth irrigation, canal water was available at the right time, hence it was preferred to the more costly tubewell water.

5.1.2.2. Madan Chapra Minor

Table 23 shows the pattern of use of sources in Madan Chapra Minor during Rabi 1991/92. This pattern is very different from that in Chakwa Minor. In Madan Chapra Minor:

a) there were no fallow or flooded fields

b) for the first three irrigations, a large and increasing number of fields (46% - 58%) could be irrigated from canal water

c) tubewell use dropped from 27% during the first irrigation to 4% of the fields by the fourth irrigation as farmers replaced costly tubewell water with canal water, and

d) few farmers actually gave a fourth irrigation. Much of the area was planted with late sown wheat, which use less irrigation. Late sowing of wheat was common because during kharif 1991 many farmers waited for rain to sow their paddy.

Table 23. Madan Chapra Minor Sources of Water for Rabi 1991/92.

<table>
<thead>
<tr>
<th>Water Source</th>
<th>No of Fields</th>
<th>Area (acres)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Rain</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Canal</td>
<td>200</td>
<td>249</td>
</tr>
<tr>
<td>Tubewell</td>
<td>119</td>
<td>64</td>
</tr>
<tr>
<td>Canal+Rain</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Other*</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Unirrigated</td>
<td>116</td>
<td>123</td>
</tr>
<tr>
<td>Fallow</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Totals</td>
<td>438</td>
<td>438</td>
</tr>
</tbody>
</table>

* This includes 2 treadle pumps (first irrigation only), and four cases of canal plus tubewell.
5.1.2.3. Shampur Minor

Table 24 shows the sources used for irrigation in Shampur Minor in rabi 1991/92. This table shows that:

a) as during kharif, the major part of the area was sown with crops which need little irrigation, mostly fruit or timber trees

b) canal water use was very small throughout the season

c) tubewell use decreased over the season

d) d) unirrigated fields increased over the season as some short duration crops (vegetables) were harvested, and

e) there were no fallow fields.

Table 24. Shampur Minor Sources of Water for Rabi 1991/92.

<table>
<thead>
<tr>
<th>Water Source</th>
<th>No. of Fields</th>
<th>Area (acres)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1  2  3  4</td>
<td>1  2  3  4</td>
</tr>
<tr>
<td>Rain</td>
<td>19 28 1 -</td>
<td>3.8 5.5 0.2 -</td>
</tr>
<tr>
<td>Canal</td>
<td>6  1 - 5</td>
<td>1.1 0.2 - 0.9</td>
</tr>
<tr>
<td>Tubewell</td>
<td>13 5 3 -</td>
<td>3.3 1.3 0.6 -</td>
</tr>
<tr>
<td>Canal+Rain</td>
<td>- 1 - -</td>
<td>- 0.3 - -</td>
</tr>
<tr>
<td>Other*</td>
<td>8 4 4 4</td>
<td>1.5 0.9 0.9 0.9</td>
</tr>
<tr>
<td>Unirrigated</td>
<td>154 161 192 191</td>
<td>42.5 44.0 50.5 50.4</td>
</tr>
<tr>
<td>Fallow</td>
<td>- - - -</td>
<td>- - - -</td>
</tr>
<tr>
<td>Totals</td>
<td>200 200 200 200</td>
<td>52.2 52.2 52.2 52.2</td>
</tr>
</tbody>
</table>

*This includes 4 plots irrigated from dugwells throughout the season and two plots irrigated from canal plus tubewell at the first irrigation.

5.1.2.4. Observations on Rabi Sources of Water

Overall, this data indicates the following:

- As expected, rainfall alone is less important than during kharif. However, it provides the needed water for a fair number of fields, at least for two of the minors.
- Canal water was important only for one of the minors. It was the only one with reasonably abundant water supplies during Rabi. This suggests that even farmers in the other two minors would make greater use of canal water, instead of depending on rain, if it were available.
- Groundwater is more important in Rabi than in kharif. However, tubewell use decreases over the season.

Farmers consider the first irrigation very important. However, canal water supplies are low because farmers upstream in the system want the water for the same purpose. Hence many farmers in the sample area use tubewell water. Over the season, farmers turn to cheaper sources of water (rainfall and canal water) or do without in order to keep their production costs low.
5.2 Low Use of Ground Water

Ground water is used far less than would be possible. Since yields are low, it would appear that more use of ground water would improve farmer incomes by raising yields. However, the low use of groundwater is caused by the high cost of pumping. We consider the use of ground water for both paddy and wheat cultivation to demonstrate this point.

5.2.1. Ground Water and Kharif Paddy Cultivation

To understand the value of ground water, we have to consider the costs and benefits of pumping. We first note that almost all the water requirements for paddy (c. 1200 mm) can be met if rainfall is average and timely. That is, a paddy crop can be grown in North Bihar without irrigation. Irrigation of paddy serves primarily to assure water is needed at the right time.

We will consider costs and benefits of ground water irrigation using figures given by farmers per katta which is the standard land unit in the area. There are 24 katta per acre or 60 per hectare.

In May 1998, one farmer in Madan Chapra Minor gave us the following per katta figures from 1998:

- Cost of plowing and leveling the field: Rs 80
- Cost of transplanting: Rs 50
- Cost of seed: none used their own seed
- Cost of fertilizer: Rs 10
- Cost of mid season labor: none used family labor
- Cost of harvesting and threshing: deducted from yield so not counted

The total per katta cash cost therefore was Rs 140. His yield (after deducting harvest and threshing costs) was 25 kilograms per katta and the prices were Rs 10 per kilogram. Therefore, the per katta return to his family labor and his capital, without considering irrigation costs, was:

$$\text{Rs } 10 \times 25 = \text{Rs } 140$$

Farmers estimate that it takes an hour of pumping to irrigate one katta of paddy. If a farmer had to pay Rs 40 per hour (the price that this farmer said he tried to charge others for the use of his tubewell), each irrigation lowers’ his returns by 36%.

In fact, however, this farmer pointed out that his 1998 yield was low; in kharif 1997 he got 80 kilograms per katta. That was a very high yield. A better estimate of a normally expected yield is about 40 kilograms per katta (2.4 tons per hectare). At that yield, and using the reported costs, the farmer’s return, without including the cost of irrigation is:

$$\text{Rs } 10 \times 40 = \text{Rs } 260$$

In this case, each irrigation by pumping ground water would lower returns by only 15%, which, however, is still considered significant by farmers. If four irrigations were given, this would lower returns by almost half.

A second consideration is the cost of pumping. Rs 40 per hour (or Rs 50 per hour in some areas) are the 1999-99 cartel price of pumping. In fact, many water buyers pay less. This same farmer
estimates that he averages Rs 28 per hour from his buyers. At that rate, and using the expected yield of 40 kilograms per katta, the cost of a single irrigation by pumping is only 11% of the returns. At our estimated operational cost of Rs 21.43 per hour (which does not include depreciation and is probably a little low), the cost of a single irrigation is only 8% of the returns. However, even at that cost, giving four irrigations from ground water would cost about a third of the returns to farming.

Thus, even tubewell owners provide all four irrigations by tubewell water to very few fields - just enough to provide rice for home consumption - even if rainfall and canal water fail. In all three sample-minors, only one field during kharif 1991 and two during kharif 1992 were irrigated all four times from tubewells.

Another key consideration is the nature of the land. Basically farmers classify land in the VBC area into two types: ordinary land and chaur land. The latter is waterlogged or flooded during kharif and well into Rabi seasons. There are large areas of chaur land in these villages; in our informants' village almost half the land is considered chaur land. Farmers cannot plant high yield rice varieties in chaur land.

Finally, as pointed out earlier, 60-70% of the farmers are sharecroppers who get only half the crop but who have to pay the full cost of cultivation. For them, the cost of pumping is doubled. During kharif 1992 - a "drought" year - some sharecroppers abandoned their paddy crops, saying that the cost of more than two irrigations from tubewells made the total cost of production greater than the potential earnings from the crop.

Pumping is thus expensive, particularly when compared with rainfall, which is free, and with canal water, which is almost free. Most farmers have to pay a small amount for canal water even if they do not get any.

5.2.2. Ground Water and Rabi Wheat Cultivation

The reasons for low use of ground water for Rabi wheat cultivation are similar to those for low use of ground water for kharif paddy cultivation. However, the average Rabi rainfall is only about 53 mm, far below the crop water requirement of 250 mm. While residual soil moisture makes up some of the difference, unlike paddy in kharif, irrigation is essential to produce a Rabi wheat crop.

5.2.2.1. A Madan Chapra Minor Farmer

The same farmer discussed in the previous section also gave us a rundown on Rabi wheat cultivation. He listed his 1998-99 per katta costs, excluding irrigation, as follows:

- Seed (2 kilograms): Rs 20
- Fertilizer (see below): Rs 67.50
- Plowing: Rs 50
- Labor during the season: No cost, used household labor
- Harvest costs: Deducted from harvest

The 1999 sale price of wheat was Rs 6 per kilogram and he got about 55 kilograms of wheat per katta (perhaps a bit higher than usual). Therefore, his total per katta cash income was Rs 330 and his total per katta costs, excluding irrigation, were Rs 137.50 for a total per katta return to labor and capital was Rs 192.50.
According to the farmers, it is possible to irrigate a katta of wheat with a half-hour’s pumping. Therefore, the costs of a single irrigation and the percentage of the returns are:

- At Rs 40 per hour (cartel price): Rs 20 and 10%
- At Rs 28 per hour (average price): Rs 14 and 7%
- At Rs 21.43 (operational cost): Rs 10.72 and 6%

For the usual two irrigations, then the cost of irrigation for a landowner is only 12-20% of his return and is clearly worthwhile, given that farmers believe that without the first irrigation the yield would be reduced by half and that the second also contributes. Farmers do not believe that the third and fourth irrigations contribute so much to the yield and can, given occasional strong winds later in the season, contribute to lodging. Thus, they are rarely willing to pay pumping costs for the second and third irrigations. However, as shown earlier, Madan Chopra Minor gets some canal water during rabi, particularly toward the end of the season, so that some farmers will give a third or fourth irrigation from the canal.

5.2.2.2. A Shampur Minor Farmer

One man gave us a detailed breakdown of his costs and returns. This was in a group interview and the others noted that, except for certain specific features of this man’s holdings, the example is representative.

Our informant gave the per katta costs, excluding irrigation, as follows:

- Seed: No cost used own seed
- Fertilizer (see below): Rs 24
- Plowing: No cost used own animals
- Labor during the season: No cost used household labor
- Harvest costs: Deducted from harvest

His production was 38 kilograms of wheat per katta. The farmers, after discussion decided that the normally expected yield is only about 30 kilograms per katta so this is better than the expected figure. Thus his total return to labor and capital, excluding irrigation costs, was:

(Rs 6 x 38) - Rs 24 = Rs 204

The irrigation costs for irrigation and percentage of returns at the various prices would be:

- At Rs 50 per hour (cartel price): Rs 25 and 12%
- At Rs 30 per hour (average price): Rs 15 and 7%
- At Rs 21.43 per hour (operational cost): Rs 10.72 and 5%

For the usual two irrigations, then irrigation costs the farmer 10-24% of his returns. Of course, it costs the sharecropper a much higher portion. It would be unreasonable then for the farmer to irrigate more than twice unless his yields were much higher. In Shampur Minor, however, unlike Madan Chopra Minor, canal water is rarely available in Rabi and does not offer an alternative.

As with irrigation of kharif paddy, pumping ground water is thus considered an expensive way to get irrigation water for Rabi wheat.
5.2.3. Irrigated Agricultural Strategies in the VBC Command

Low yields are a major reason that the cost of ground water irrigation forms such a large fraction of farmers’ returns to their labor and capital. However, except in chaur areas, the soils and climate conditions are excellent in North Bihar. Low yields thus are the outcome of choices made by the farmers.

The per katta amounts of fertilizer reportedly used in these three cases were:

- Madan Chapra Minor farmer for paddy: 2 kg urea
- Madan Chapra Minor farmer for wheat: 5 kg diammonium phosphate, 2.5 kg urea, and 0.5 kg potash; given in three applications
- Shampur Minor farmer for wheat: 2 kg diammonium phosphate, 1 kg urea, 1 kg potash, and a little zinc

These are low amounts, particularly for paddy. They indicate that the farmers have adopted a low-input low-yield strategy. In the 1992-93 study, the great majority of farmers operated with such a strategy. In our 1999 interviews they gave us the following reasons for this strategy:

- Getting good seed is costly and difficult because it is not available locally.
- Fertilizer is available locally, generally not from government but only private sources. All the farmers feel that private fertilizer is adulterated as well as more expensive than fertilizer obtained through the state government.
- Sharecroppers get such small returns that they carefully watch every cent of expenditure and thus keep costs low.
- Cash flow is a problem and farmers often lack the cash to purchase larger amounts of fertilizer.
- There are other problems related to social conditions. In May 1999, two farmers told us that some of their fields were harvested at night by others and that, although they know who did it, they are afraid of being beaten or killed if they protest.

At least some farmers are aware of alternative farming strategies. One of our informants mentioned that he had tried high quality wheat seed one season - he had to get it from Patna, the state capital - and got excellent yields. The others indicated that they knew that with better fertilizer, for which they would have to use more water, they could get significantly better yields. However, in the present circumstances, they feel they cannot adopt such strategies.

5.3. Installing a Private Tubewell

Given that ground water is a costly form of irrigation, even for a well owner, the question arises when a tubewell is a good investment.

Farmers told us that, installing a new tubewell costs about Rs 100 per foot including drilling, pipes, and fittings. Assuming that a farmer installs a new 60-foot tubewell without subsidy, it will cost him about Rs 6000. A used pumpset will cost somewhat over Rs 5000. Thus, the total cost is Rs 11,000. Assuming a 20-year life span, the capital cost of the well is Rs 550 per year.

Let us assume that having the reliability of a groundwater supply increases paddy yields by 100% - i.e. from an expected yield of 20 kg per katta to the presently expected yield of 40 kg per katta under the present low-input low-yield farming strategy. Let us also assume that a farmer would get
no wheat crop without irrigation; thus all of the expected 30 kg per katta yield depends upon the presence of ground water irrigation facilities.

Using 1998-99 prices, this means that, for each katta, a tubewell would increase a farmer’s cash revenue by:

\[(\text{Paddy: Rs 10} \times 20) + (\text{wheat: Rs 6} \times 30) = \text{Rs 380}\]

Assuming two irrigations from ground water per season, the operating costs of the tubewell would be:

\[(\text{Paddy: Rs 21.43} \times 2) + (\text{wheat: Rs 10.72} \times 2) = \text{Rs 64.29}\]

Leaving an annual profit of about Rs 316 per katta from the crops irrigated by the tubewell. Based on these figures, installation of a tubewell would be valuable for any farmer who owned at least 2 katta of good (i.e., not chaur) land.

At the present time, because wells are not rare, the cost of buying a tubewell has to be weighed against the cost of purchasing water in the market. Even at a cost of Rs 50 per hour (the cartel price quoted to us in Shampur Minor), the cost of giving two irrigations to a single crop is only Rs 150 per katta and thus wells below the value of the additional crops. There is a third alternative, namely to plant tree crops and others that do not require irrigation (in part because of the high water table). As mentioned earlier, this is a strategy being adopted by a significant number of farmers in the Shampur Minor area because their access to cheap canal water is so bad.

Thus, while farmers want tubewells, at the present time they are not essential since farmers have alternative sources of water, including ground water, and alternative cropping strategies that do not require irrigation.

A big problem is cash flow. Many farmers find it very difficult to gather a lump sum needed to purchase a tubewell. Government subsidy programs thus appear to be important not only because they lower the cost of well installation and of purchase of pumps, but also because they allow payment over time. However, the transaction costs of getting a subsidy (farmers told us that needed bribes can cost Rs 3000 to 4000) may make it difficult to purchase a well even if one is eligible for a subsidy.

A final consideration is the benefit from selling water. Most farmers who install a tubewell hope to sell water, at least enough to cover the costs of irrigation of their own land. However, as we have pointed out earlier, selling water is with its troubles, particularly collection of fees, and at least some well owners prefer not to try it. Our data seems to suggest that no farmer will get rich selling water, although another study in the same area (Shah and Ballabh, 1997) suggests that tubewells are generating significant wealth for the owners.
6. PERFORMANCE OF CONJUNCTIVE MANAGEMENT IN THE VBC COMMAND

6.1. WATER DISTRIBUTION PERFORMANCE

In Section 3.4, we documented the problems with canal management that make canal water unreliable and even unavailable to many farmers in the VBC command.

Water from tubewells and from river lift pumps (where available) is highly reliable and distribution is not particularly problematic, in part because of the availability of pipes to help with distribution.

Conjunctive management in the VBC area consists of the use of tubewells (and river lift) to supplement rainfall and canal water. Tubewells are needed largely because not only the canal water is unavailable in all parts of the command, but also canal water is unreliable. Indeed, for many, water from canal is less reliable than rainfall.

On the other hand, because of social and economic conditions, farmers have adopted a low-cost low-yield farming strategy that leads them to minimize costs. In so doing, they attempt to minimize pumping of ground water in favor of dependence on rainfall and canal water, or in favor of no irrigation. Thus while installation of a tubewell is valuable, operation of that tubewell will be minimized.

Overall, then conjunctive management is a reasonable but expensive way to assure decent water distribution in the area.

6.2. AGRICULTURAL PRODUCTION PERFORMANCE

We have no way to evaluate the total production of the VBC area. The sole criteria we can use to evaluate agricultural production in the area are by means of reported yields.

Yields are low. Madan Chapra Minor farmer reported the yield for paddy as only 25 kilograms per katta or 1.5 tons per hectare. His yield for wheat, however, was more respectable - 3.3 tons per hectare. The Shampur Minor farmer’s yield for wheat was only about 2.3 tons per hectare. These yields agree well with those reported for Bihar State as a whole.

However, we have argued above that the low level of production is not due to failure of conjunctive management, but rather to social and economic problems.

6.3. ENVIRONMENTAL MANAGEMENT

The most important environmental problem associated with irrigation in North Bihar is waterlogging. About 900,000 hectares in Bihar suffers from waterlogging. Out of this nearly 800,000 hectares lie in North Bihar. Most of this is in the command areas of the Eastern Gandak, Kosi, and Western Kosi Irrigation Systems. The main causes of waterlogging include:

- High intensity of rainfall with deficient drainage capacity.
- Inadequate drainage of surface water due to unfavorable drainage conditions.
- Obstruction in the drainage channels by construction of fish barriers, bunds, etc.
As mentioned earlier, in two villages, one under Madan Chapra Minor and one under Shampur Minor, farmers claim that 50% of the land is chaur land. Under Chakwa Minor, there are significant amounts of land that flood every monsoon season.

Construction of the surface system has aggravated waterlogging in some areas. Along certain reaches of the canals, earth was removed from borrow pits to form bunds; many of these flood regularly during the monsoon. This is the primary problem in the Chakwa Minor area. In other areas, seepage from the canals adds to the already high water tables and increases the chaur areas. However, farmers believe that the biggest problem associated with the canals is that they have blocked whatever natural drainage there was, thus increasing waterlogging.

A comprehensive plan for removing drainage congestion of North Bihar has been prepared and the Water Resources Department has taken up some schemes in the Gandak and Kosi Command areas. Another plan on Integrated Drainage Project has been submitted to the Central Government Planning Commission to benefit 250,000 hectares.

It has been suggested that promotion of ground water irrigation could help resolve some of these problems (e.g. CWRS, 1993). However, given the limitations on pumping caused by the social and economic conditions in the area, it seems unlikely that tubewells will solve the problems.
7. OPPORTUNITIES TO IMPROVE THE RESULTS OF CONJUNCTIVE MANAGEMENT

As expected the basic finding is that in the Vaishali Branch Canal command of the Eastern Gandak Irrigation System in North Bihar conjunctive management of surface water and ground water for irrigation is being effectively carried out by individual farmers subject to several major constraints. These constraints include:

- The surface water is taken from the Gandak River and is carried in a canal system. However, the physical design and condition of the canals and defects and problems with the management of the canals by the Bihar State Water Resources Department and the Gandak Command Area Development Authority make canal water unreliable and canal irrigation ineffective and problematic in the study area.
- Ground water is plentiful and is available at shallow depths all year round. Also, with help from government subsidies, there has been massive development of tubewells to exploit this ground water both in the VHC command and elsewhere in North Bihar. However, the usefulness of these tubewells is severely constrained by the economics of farming in North Bihar and by social conditions that induce farmers to follow a low-cost low-yield farming strategy.

Thus while conjunctive management makes water available to all who want it, whenever they want it, either from their own wells or from the water market, both supplementing rainfall and canal water, it does not lead to high levels of agricultural production or high levels of profitability for farmers.

Also, the presence of the canals aggravates waterlogging problems in some areas while the limitations on pumping fail to reduce the waterlogging problems.

This analysis suggests the following opportunities for action to make conjunctive management more useful:

7.1. CONJUNCTIVE MANAGEMENT AT GOVERNMENT LEVEL

The canal system is a major source of water, but, unlike the tubewells, it is not under the control of the water users who alone carry out conjunctive water management for irrigation. In order to provide improved conjunctive management, there is a need to get the government agencies to take cognizance of conjunctive management.

At the moment, there is no such cognizance. In the Gandak Command and in the other major irrigation systems, there is no coordination between the Water Resource officers and the Minor Irrigation officers. Staff receives orders from their respective heads and provides information to their heads. Decisions are taken independently, even though their functions are mutually dependent on the same resource base. An Executive Engineer, who has worked in both the Departments, reported: “They (the field officers) are supposed to work according to guidelines from above and are answerable only to vertical hierarchies.”

The Minor Irrigation Department staff is organized on the basis of administrative boundaries (blocks and districts). Canal irrigation staff are organized according to hydraulic boundaries. Within many branch canal commands, there are large areas that, like the Vaishali Branch Canal
Command, are under both surface and groundwater irrigation. Without some common basis, however, the officials in the separate departments have difficulty in cooperating.

The State of Bihar has no clear-cut policy guidelines for effective conjunctive use. Its executive agencies - the Water Resources Department (WRD) and the Minor Irrigation Department (MID) - have not spelt out a vision and action plans on conjunctive use. Promoting conjunctive use is listed as a major function of the state Command Area Development Authorities. In practice, however, little attention has been paid to it. Worst of all, no state agency is monitoring the use of ground water effectively in canal systems, so that there is not only no policy but also no decent information about conjunctive water use.

Recently, there has been movement toward development of a policy. Following recommendations from the Government of India, the Minor Irrigation Department has decided to allow the installation of state tubewells within canal commands to serve areas where it is difficult to push the canal water. However, this is a very small step, particularly since the state tubewells provide a relatively small portion of the ground water for irrigation and because they have extensive operating problems.

The Second Irrigation Commission (GOB, 1994) did no more than issue a statement that conjunctive management should be practiced, without considering how to do so. Their report is almost exclusively focussed on canal irrigation. However, they did strongly urge consideration of management of water resources by basins.

Management by basins would resolve one of the present major problems, the separation of state power over water for irrigation into two independent departments: the Water Resources Department and the Minor Irrigation Department. This separation means that the personnel in neither department know about the full range of water resources being used in any one area and thus they plan investments and interventions without taking these other water resources into account.

In our opinion, it is best to keep conjunctive management for irrigation as such in the hands of the farmers. However, the state can provide support to the farmers in the following ways:

- By monitoring and providing information on all water resources in a manner that makes all the relevant information available through a single source. That is, data from the monitoring of ground water done by the Minor Irrigation Department (supplemented by monitoring information provided by the Central Ground Water Board) should be reported on the same basis as data from monitoring use of surface water and should be available from a single agency.
- By finding effective ways to give farmers power to jointly manage the canal systems with the government agencies.
- By providing effective support for agricultural development, including subsidies for tubewell installation, to enable farmers to make better use of ground water resources.

Our earlier study (Raju et al., 1994) on groundwater use in the Gandak Command area concluded that, there is no capacity to manage total water resources equitably, sustainably and efficiently. Distributing the same amount of surface irrigation water to areas differing in availability of groundwater may be neither equitable nor efficient. Within the Eastern Gandak Command, the high water table means that large areas are susceptible to waterlogging and damage from salinity and alkalinity. Neither threat can be controlled without a more coordinated effort at management of all water resources. The lack of conjunctive management at the group level in an environment of
extensive conjunctive use at the individual level is somewhat like having two cooks preparing parts of the same meal, from the same limited food supply source, but without any communication, about how much of the food stock the other is using nor what type of food, nor how much of it, the other is preparing (Raju and Vermillion, 1993).

7.2. CONJUNCTIVE MANAGEMENT TO REDUCE THE WATERLOGGING

As already pointed out, waterlogging is a major problem in North Bihar. Almost all recommendations to deal with waterlogging have focussed exclusively on improving drainage. Clearly, improved drainage is essential in North Bihar. However, properly conceived conjunctive management could play a part (cf CWRS, 1993).

The theory is simple: farmers should pump their irrigation water in areas where there is value in lowering the water table. Lowering the high water table over the whole area would help in general. One could argue that it was a mistake to build canal systems in North Bihar.

However, given the present existence of the canal systems and the fact that, to farmers, they provide less expensive irrigation water than do tubewells, there is a demand for canal irrigation. The problem then has two dimensions:

- To determine and enforce the optimal pattern of providing canal water so that it does no harm.
- To develop means to encourage farmers to pump ground water for irrigation in areas where pumping will help reduce waterlogging.

The difficulty of the latter concern is obvious; farmers prefer cheaper water when it is available.

The solution lies in institutions that allow farmers to spread the costs of irrigation over both sources so that all can be served more or less fairly at similar costs. This implies that canal water rates should be raised significantly - probably possible only if canal performance is improved - and some of the funds used to subsidize ground water irrigation in areas where pumping is desired.

While this is a major institutional development problem, it could conceivably be done since similar cost and benefit sharing arrangements exist elsewhere.

7.3. CONJUNCTIVE MANAGEMENT FOR POVERTY ALLEVIATION

Although often discussed (e.g. Kahnert and Levine, 1993), this analysis suggests that the use of ground water for irrigation, either alone or conjunctively with surface water, is not likely to serve as an engine of rural economic growth in the immediate future, although it has that potential. The constraints are not water constraints; they are political, institutional, social, and economic.

However, if better conjunctive management can resolve the waterlogging problem, it will certainly raise output and provide some help for the rural poor.

Ultimately, however, the state must address the underlying social and economic conditions that keep farmers from expanding their output. Examples of such reforms would be:
• Land or other reforms that reduce the percentage of share croppers.
• Improvements in security so that farmers need not fear theft of their crops or other such disturbances.

Without such improvements, working on conjunctive management is likely to have only marginal effects.
8. REFERENCES


