Management Information Needs for Groundwater Irrigation Within a Large Canal System

Introduction

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Surface and groundwater irrigation are often interdependent in canal irrigation systems in India. Most studies of groundwater irrigation focus on use, misuse, over use or under utilization of groundwater, as a resource separate from surface water. Many of such studies, however, are carried out in command areas of large canal irrigation systems.

In the State of Bihar in India, within large canal irrigation systems, canal water is distributed (not necessarily "managed") by the Irrigation Department, while groundwater investigation, planning and promotion of state tubewells are done by the Minor Irrigation Department. On the other hand, groundwater utilization by private (i.e., individual) tubewells proliferates on its own, mainly as an answer to a growing demand by farmers for easy access and reliable control over the resource. There is virtually no government control over the use of these private tubewells. River surface lift irrigation units have been installed by the Minor Irrigation Department. There is also a large number of private lift irrigation operations on river systems. The Minor Irrigation Department has installed state tubewells, with the objective of helping marginal and small farmers.

The purpose of this paper is to present a practical information base, which could be used to support management decisions regarding canal irrigation systems that have extensive groundwater and surface lift irrigation within canal command areas. The proposed Groundwater Irrigation Inventory for Canal Systems is intended to support enhanced conjunctive management of canal and lift irrigation water in a more efficient and sustainable way. Its aim is to better integrate information about the two sectors in management decision making. This can be done both at the level of the Irrigation Department and at the level of group farmer organizations, either at the field or subminor canal levels.

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PRESENT SITUATION

Field level functions of the Irrigation Department and the Minor Irrigation Department are performed without any coordination. Staff receive orders from their respective heads and provide feedback up the hierarchy. Decisions are made independently, even though their functions are closely and mutually dependent upon the same resource base. Although both Departments belong to the higher-level Water Resources Department, very little planning or management occurs jointly between them.

Minor Irrigation Department staff are organized on the basis of administrative boundaries. Irrigation Department staff are organized according to hydraulic boundaries. Within many branch canal commands in India, there are large areas (in some cases the whole block) which are under both surface and groundwater irrigation. While the common resource is often *used* conjunctively,[2] it is rarely *managed* conjunctively, at least beyond the individual farmer. One Executive Engineer, who has worked in both Departments, reported, "They [i.e., officials] are supposed to work according to guidelines from above and are answerable only to vertical hierarchies." There are virtually no horizontal linkages between these two Departments.

The same Executive Engineer also mentioned that, "when canal irrigation systems were designed and operated, it was thought that the whole area under the command could be fully irrigated by canal water. Hence, it was thought that only the Irrigation Department would need to be in charge of the area." When most large canal systems are constructed or rehabilitated in India, or when the operations and maintenance (O&M) practices become set routines, the Irrigation Department gives little, if any, official consideration to the utilization of available groundwater in canal commands. This is the case for providing full irrigation to unirrigated areas in the command area, and for supplementary irrigations during periods of surface water shortage.

As observed in large canal systems in the State of Bihar, surface irrigation targets are planned and distributed often without reference to the extent or utilization of groundwater irrigation. Furthermore, the extent of groundwater irrigated area within a crop season, and across crop seasons, is not reported in the irrigated area figures of branch canals.

Such local-level lapses in data and management constrain the capacity to manage water resources equitably, sustainably and efficiently. Distributing the same amount of surface irrigation water to areas differing in availability of groundwater is neither equitable nor efficient. Both waterlogging and salinity are becoming severe threats to the sustainability of irrigated agriculture. This can often be attributed to the failure of effective surface and groundwater management.

India's Eighth five-Year Plan (1992-97) rightly notes that, "the plan estimates of potential [irrigated area] created do not distinguish between the gross area irrigated by groundwater as a sole source and as a supplement to surface works" (Government of India, 1992). 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 independently preparing different parts of the same meal, from the same limited food supply source, but without any communication about how much or what type of food stock the other is using, nor how much of it the other is preparing. Without coordination, the results may be too much, too little or harmful combinations of food.

Whether for planning further water resource development, facilitating conjunctive management, or for environmental monitoring of human impact on water resources, there is a need to establish information bases about the availability and existing utilization of groundwater within large canal systems. This can then be used as decision support for conjunctive management of irrigation water.

The Study Area

This study has been carried out in a groundwater-rich area of North Bihar, India. The Vaishali Branch Canal (VBC) of the Eastern Gandak Project was selected for this study. The objective was to test a practical method to obtain an information base on different water sources used for irrigation, and on water use patterns in three sample minor canal commands of a large canal system.

The VBC takes off at RD (Reduced Distance) 553.89 of Tirhut Main Canal (see Figure 1). It has a maximum head discharge of 36.95 cumecs (1,304 cusecs). The command area of this canal is bordered by Baya River and Bhushali Distributory Canal on the west and Jaitpur Branch canal on the east. The Gross Commandable Area (GCA) of this branch canal is 90,413 ha. The Culturable Command Area (CCA) is 63,289 ha. The breakdown of the annual surface irrigation as adopted in the Project Report of the Irrigation Department is as below:

a) Kharif 70% of CCA	44,302 ha
b) Rabi 35% of CCA	22,151 ha
c) Hot weather 8% of CCA	5,063 ha
d) Perennial 7% of CCA	4,430 ha
Annual irrigation 120% of CCA	75,946 ha

The topography of the command area is such that the canal has to run across valleys and ridges alternatively. The branch canal cuts through high land and has filler through low reaches. Water courses above one cusec discharge are being constructed by the project. Field channels below one cusec capacity are being constructed by Gandak Command Area Development Authority (CADA). Many water courses constructed earlier have become inoperative on account of non-use or poor maintenance. Most of the channels constructed are not in use for want of proper linking arrangements between outlets and channels constructed by CADA. Many outlets have been damaged. As a result, when water is available in the canal, villagers resort to flooding their fields by cutting the canal, distributaries, minors and the water courses.

The practice of field-to-field irrigation contributes to the already existing problem of waterlogging. Where the branch canal cuts through high spots, in the absence of parallel channels to irrigate high patches of land, cultivators cut the canal. Where the canal goes through filled low land, there is appreciable seepage from the unlined canal banks. The seepage water creates a waterlogging problem, which the cultivators of low lying banks resent.

Since the commissioning of the canal, water has generally not been delivered to farmers on time. The water supply system in different canals is primarily based on the need of specific canal commands. The official approach is to try to run the distributaries, sub distributaries, minors and water courses at their full supply level so that these canals may run with non-silting and non-scouring velocity. The branch and Main Canal are, however, the exceptions in which discharge varies with respect to the water requirement within a certain period -- the period of water indent is often 10 days).

In practice, there is often no water in the branch or distributary canal at the time of need. Actual discharge versus the designed discharge, and annual irrigation in different seasons against what was planned, is presented in Table 1.

It is evident from the above table that the canal has run with only 30 to 32 percent of the design discharge and the area irrigated during different crop seasons is only 5 to 11 percent of the culturable command area (CCA). According to original design parameters, this branch canal was supposed to irrigate 63,289 ha. Potential created so far is only 17,200 ha. of CCA. At the beginning of every season, the Irrigation Department fixes the targets and at the end of season it

Fig. 1 SCHEMATIC DRAWING OF VAISHALI BRANCH CANAL

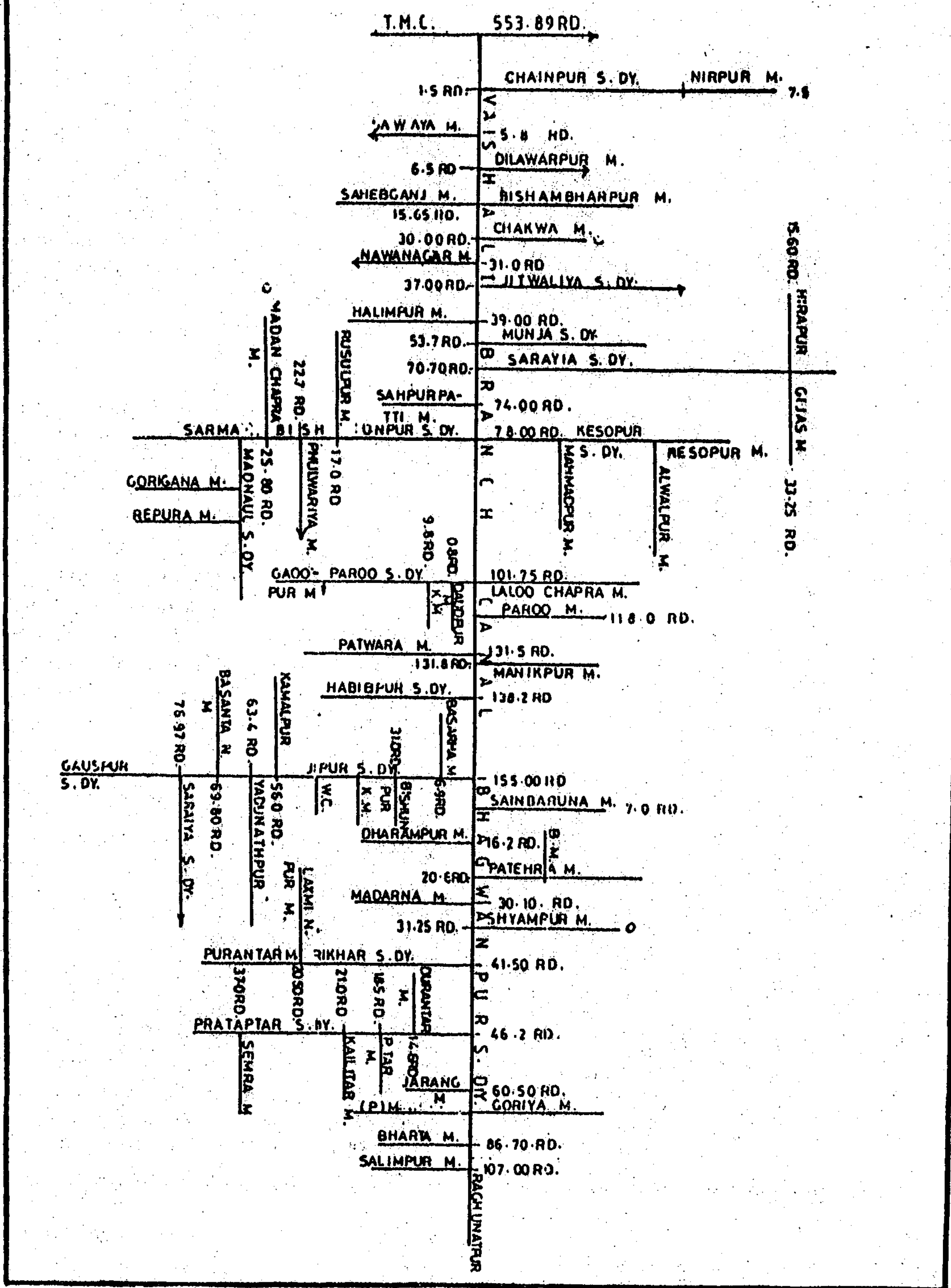


TABLE 1. **Discharge and area irrigated as designed and achieved in Vaishali Branch Canal.**

Year	Design discharge in cumecs (cusecs)	Actual discharge in cumecs (cusecs)		Irrigation envisaged in the project in ha.		Irrigation achieved in ha.	
		Kharif	Rabi	Kharif	Rabi	Kharif	Rabi
1986-87	36.95 (1304)	13.34 (400)	8.50 (300)	44,302	22,150	-	3,500
1987-88	36.95 (1304)	11.34 (400)	7.09 (250)	44,302	15,506	6,625	2,975
1988-89	36.95 (1304)	12.76 (450)	7.09 (250)	44,302	15,506	7,000	2,515
1989-90	36.95 (1304)	12.76 (450)	7.09 (250)	44,302	15,506	6,313	2,591

Source: *Office of the Executive Engineer, Saraya, 1992*

measures the achievements. During 1992-93, target and achievement figures were as follows:

Season	*Target*	*Achievement*
Kharif	15000 ha.	10005 ha.
Rabi	2500 ha.	2010 ha.

Given faults in design and construction, and poor maintenance during the 1992 Kharif Season, the VBC irrigated only 10,000 ha. Representing one-sixth of the designed command area, its water deliveries are often inadequate and unreliable.

Ground water

The entire Gandak Project area is underlain by alluvial deposits which attain a maximum thickness of about 2500 m in parts of North Bihar, and thin to feather edges where it meets Siwalik sediments of the Himalayan foothills. The alluvial sediments of the soil profile consist of sand of various grades, silt, clay and *kankar*. The aquifers are formed by clean sand beds which constitute between 40 and 80 percent of the section. The depth of the water table from ground level is around 4 meters during pre-monsoon and rises to around 2 meters during post-monsoon period, in the study area.

The existing district level water balance data are crude, inaccurately assessing the potential water resources available. The ground water reservoir is essentially full in extensive areas before the end of the wet season. The recent Groundwater survey carried out during 1986-87 (Ministry of Water Resources, 1991) indicates, however, that the two districts in which this study area is located have considerable undeveloped ground water resources; to the extent of 64% of the CCG in Muzaffarpur District and 52% in Vaishali District.

In the study area, utilization of different sources of water are administered as shown in Table 2.

TABLE 2. **Irrigation Sources and Administrating Authorities.**

Source	Operated by	Main function	Other functions
I. Canal water	Irrigation Dept.	Water distribution	Canal network development & O & M
II. Ground water	a) Minor Irrig. Dept.	State tubewells	Installation and O & M
	b) Individual	Prvt. tubewell	All related functions.
	c) User groups	group tubewell	Partly installation and O & M.
III. River Lift Irrigation	Minor Irrig. Dept.	Lift irrig. unit	Installation O & M

The basic problem is that groundwater, lift irrigation and surface canal irrigation water are combined at the field level to meet farmers' needs. The acquisition and delivery of one source of water without regard for the availability and use of other sources, will inevitably lead to inefficient and inequitable water use and possibly to environmental problems such as waterlogging or salinity. The purpose of the inventory is to provide a practical method for obtaining a minimal information base which could support conjunctive management of the total water resource base in large canal systems where farmers also use groundwater for irrigation.

STEPS IN DEVELOPING THE GROUNDWATER IRRIGATION INVENTORY

Given the way the irrigation resource is divided up administratively, future use of the Inventory method depends on the ability to link the different departments to develop a new conjunctive resource use, information and management system. The following steps were taken in developing and implementing the pilot inventory, in collaboration with the departments concerned.

1) A map of the Vaishali Branch Canal (VBC), showing the canal network and command areas, was obtained (see Figure 1 for VBC schematic diagram).

2) Based on the area indicated, data was collected both for hydraulic boundaries and for villages, partly or fully irrigated by each hydraulic boundary.

3) It was found that the branch canal has 32 hydraulic sub-units (including minors and sub-minors) and 208 villages which are partly or fully irrigated.

4) For each of these villages, based on the 1981 demographic census and the 1986-87 groundwater census, preliminary estimates of the location and area irrigated by source type (surface and groundwater) were identified.

5) After obtaining area irrigated figures during the 1992 Kharif Season, and making reconnaissance inspections in the field, three minors (in head, middle and tail end of VBC) were selected for detailed data collection (see Figure 2 for a sample minor i.e., Chakwa minor located in the head reach of the branch canal).

6) To help in the first round of field data collection, key informants were selected from each village. Informants were selected who a) knew the whereabouts of all or most irrigated village plots, b) knew about plot-wise crops and irrigation sources (by current and previous seasons), c) could make village-level maps, and d) could communicate easily with all caste and social categories of farmers of the village.

7) Study team members and informants walked through the sample minor commands with village-level maps, sited each tubewell, and identified its location on the map (see e.g., Figure 3).

8) Depending on the type of data collected, data related to each tubewell was recorded on the basis of direct observation or information obtained from the key informants.

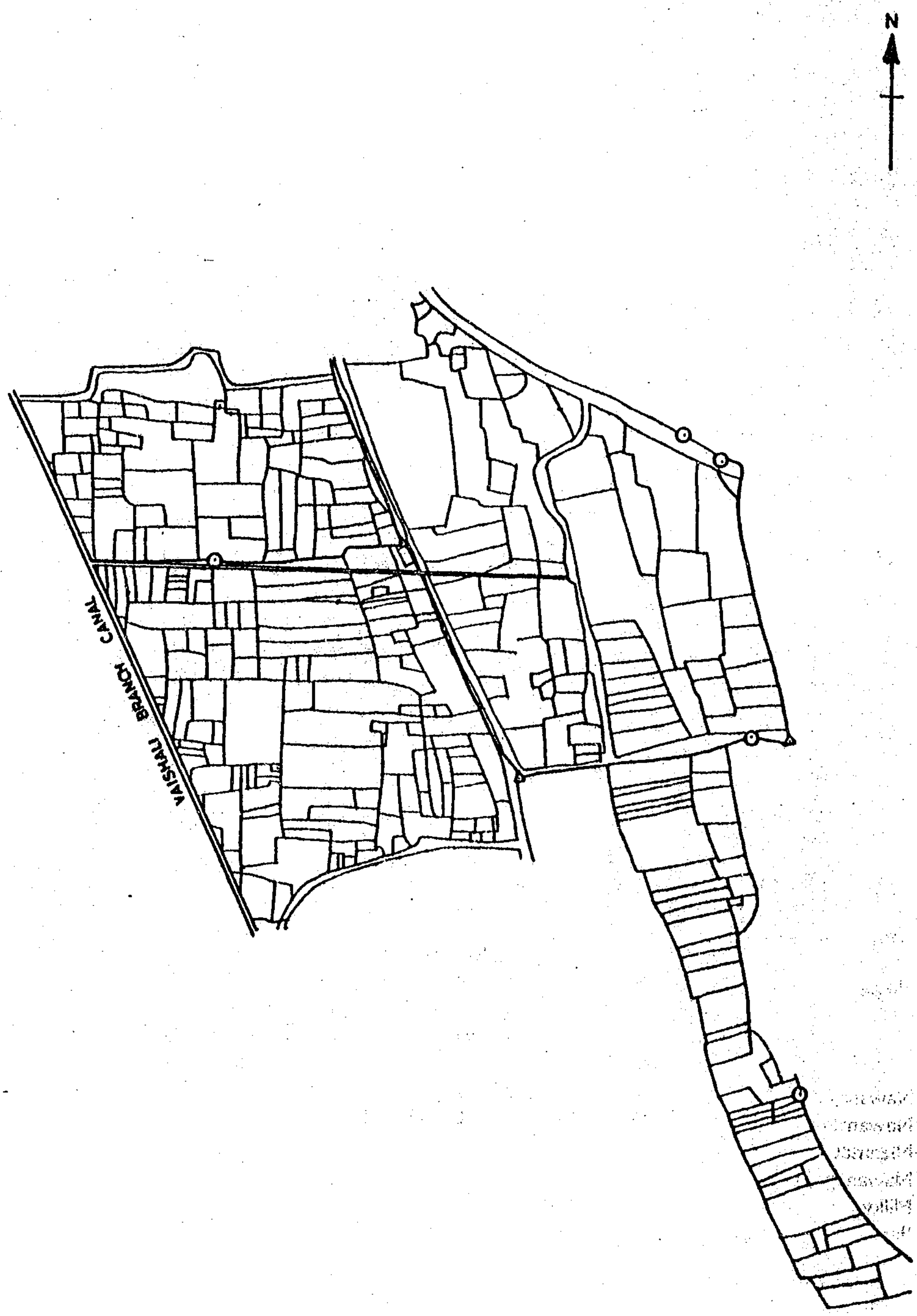
In the command area of selected minors, the study attempted to identify the:

a) field-wise source of irrigation for four crop seasons;

b) location or spatial pattern of tubewells;

c) number of functional and defunct tubewells and reasons for defunct;

Fig. 2 CHAKWA MINOR



d) extent of groundwater use across seasons and crops for which it has been used;

e) physical features of tubewell structures;

f) efficiency rates of machines;

g) estimates of annual machine-running hours for owner's and buyer's fields;

h) extent of groundwater markets in operation;

i) extent of subsidy scheme beneficiaries and ultimate use of items provided under this scheme;

j) productivity levels of different crops irrigated by groundwater and surface water;

k) extent of groundwater, canal water and conjunctive water use patterns;

l) role of groundwater-related institutions;

m) role of groundwater agencies in the installation and management of tubewells.

From the study, a more abbreviated set of indicators was identified which expressed spatially, the extent and nature of groundwater and surface irrigation use patterns. Village key informants in all cases readily identified all tubewell locations and water sources by field, which were later verified through field observation and interviews with farmers.

Annex 1 provides a list of the kinds of information collected in 1993 for the pilot Groundwater Irrigation Inventory for Canal Systems. Much of the information obtained from this Inventory is in the form of approximations based on field observations and the local experiential knowledge of farmers and knowledgeable farmer informants. At first glance, an engineer might balk at the approximate nature of the information obtained. However, given the virtual absence of any information base which is usable by canal system managers, this practical inventory approach allows for improved estimates of irrigation requirements.

Data collected and processed through this method showed enormous differences between official records and study data measurements as described in the following sections. Due to space constraints, data pertaining to only one minor (Chakwa) out of three selected minors, is presented.

Chakwa minor: It is located in the head reach of the VBC and irrigates parts of four villages.

TABLE 3. **Growth of Tubewells in Chakwa minor-number and area (acres) irrigated.**

Name of Village	1981 Demography Census		Groundwater Census (1986-87)					Farmers Survey					
			Area irrigated				No	1970 to 1980	1980 to 1985	1985 to 1990	1990 to 1992	Total No	Area
Nawanagar	No	Area	No	Kharif	Rabi	Total							
Nawanagar Nizamat	NA	20.22	16	28	25	53	20			1		1	4.26
Nawanagar Milky	NA	NA	1	121	16	37	11		1	1	1	3	7.98
Rampur Khurd	NA	NA	6	11	8	19	15	1				1	14.80
Jagdishpur	NA	1.67	6	10	7	17	10	1		1		2	12.1
		21.89	39	70	56	126	56	2	2	3	1	7	42.18

The growth of tubewells in Chakwa minor is presented in Table 3. Though canal irrigation was started in 1974, all seven tubewells in the study area were drilled after 1974. There is a clear indication of unreliability and inadequacy from the early beginnings of the canal irrigation. As years passed, uncertainty of canal irrigation has rapidly increased; out of 7 tubewells, 4 were drilled in the last seven years (1985-1991).

However, two tubewells have become defunct in the study area (see Table 4). The first, installed in 1982, was used until 1989. The manager of the tubewell sold the diesel engine needed to run the system in 1989 due to frequent engine problems, theft of engine parts, and a high repair cost. Due to lack of funds, he could not purchase a new diesel engine. The second, a scheduled caste farmer, received boring pipes, subsidized 100 per cent, from the block office in 1989. Although assured one, he never received a diesel engine from the block office. Because he was unable to mobilize money on his own to purchase a diesel engine, after four years, the pipes still remain unused.

In the study area, the cropping pattern is mainly paddy in *Kharif*, wheat and maize in *Rabi*, and in the summer most of the plots are kept fallow. Other crops grown in small areas are vegetables and pulses. Important varieties of paddy grown here are local varieties like *Bakoi* and *Bhadya*, followed by high yielding varieties like *Pusa 34*, *Sita* and *Jaya*. Yields are comparatively higher in HYV (978 kg/acre) than in local varieties (745kg/acre). Lowest yield rates (460 kg/acre) are in *kala* britch variety, spread over 9 months, usually grown in *chaur* area by broadcasting method.

Out of 54 acres of study area, more than five acres is permanent "water stored area", locally referred to as a '*Chaur*' area. During the end of Kharif 1992, when we measured the area with the farmers, the depth of the water stored varied from 3 to 7 feet. According to farmers, this area located along the VBC, was originally depression area. During VBC embankment construction, soil from this area was dug out, increasing the depression. Regular seepage from VBC and accumulation of rainfall water, in the

TABLE 4. Status of tubewells in the villages of Chakwa minor

Name of Village	As per Ground water census	Based on field survey						
		Within study area	Outside study area	In study area			Outside study area	
				Total	Functional	Defunct	Functional	Defunct
1.	2.	3.	4.	5.	6.	7.	8.	9.
Nawanagar Nizamat	NA	1	19	20	1	16	3	
Nawanagar Milky	NA	3	8	11	1	2	7	1
Rampur Khurd	NA	1	14	15	1	12	2	
Jagdishpur	NA		10	10	-		7	3

Note: a) NA = Not Available in the report.
b) Col. 4 includes kharif 1991 & Rabi 1991-92 area irrigated by 5 tubewells, while remaining two are defunct. Out of 5, 2 are located outside study area, but irrigates inside.

Source: a) For Col.2 & 3 : Population census 1981, Part X(A),
b) For Col.4,5 & 6 : Groundwater Census (1986-87), Sahebganj Block.

absence of drainage, has also increased the water stored area.

For cultivators of this water stored area, VBC is viewed more as a problem than as a solution to alleviate their poverty. Local farmers said (for which local irrigation officials also personally agree) that, due to political pressures, the VBC's original design has changed dramatically. For the same reasons, the canals and distributaries, are called 'political canals'. We observed similar problems, resulting from 'political canals' in most parts of the VBC, both at its head and tail reaches.

The study area covered a total of 164 plots actually falling under the canal irrigated area. This area was demarcated. As we moved through our survey, we found that not all plots are irrigated by the canal. Based on a survey of each plot, using spot checking followed by discussions with the respective cultivators, different sources of irrigation were recorded for Kharif 1991, Rabi 1991-92, Summer 1992, and Kharif 1992. Table 5 and Table 6 present different sources of irrigation during Kharif 1991 and Rabi 1991-92.

Technical Aspects

The Inventory may enable policy makers to estimate the effective annual movement of water tables in different sections of a canal system. It is reported at present that aquifer draft in the study area is only 25 to 40 percent of annual recharge caused by rainfall (CWRS, 1993). However, the measurement basis for such water balance estimates is generally quite weak. A more practical approach is to simply monitor water table movement periodically, as is included in this Inventory.

Farmers in the study area reported that original or good quality spare parts are not available in the local market and suitably trained engine mechanics are not available on a timely basis. Inventory data on the levels of functional or defunct tubewells can be used to monitor such problems. It can also be used to understand, both by users and officials, present levels of tubewell discharge and diesel consumption, and to calculate the efficiency levels of engines. Our study indicated that at present, diesel engine efficiency levels are very low (8%). Out of 26 tested engines, 23 have lower than 35%

TABLE 5. **Multiple sources of irrigation in Chakwa minor during Kharif 1991 & Rabi 1991-92.**

IRRI	KHARIF 1991							
	1		2		3		4	
SOURCE	No of Plots	Area	No of Plots	Area	No of Plots	Area	No of Plots	Area
Canal	3	0.78	16	3.28	47	10.68	109	31.25
Canal+Rain	14	2.30	4	0.77			7	3.22
Rain	83	24.70	88	24.42	102	36.07	41	15.03
Tubewell	56	21.44	48	20.75	7	2.99	1	0.90
Total :	156	49.22	156	49.22	156	49.74	158	50.40

TABLE 6. **Multiple sources of irrigation in Chakwa minor during Rabi 1991-92**

IRRI	RABI 1991-92							
	1		2		3		4	
SOURCE	No of Plots	Area	No of Plots	Area	No of Plots	Area	No of Plots	Area
Canal	3	0.76	5	1.41	14	3.61	39	10.79
Canal+Rain								
Rain	45	12.66	51	15.34	60	18.72	61	25.37
Tubewell	50	21.46	41	17.23	24	12.37	1	0.90
Total :	98	34.88	97	33.98	98	34.70	101	37.06

TABLE 7. **Efficiency of diesel pumpsets.**

Particulars / Minors	Chakwa	Madan Chapra	Shampur
1. No. of pumps tested (all 5 h.p)	4	10	12
2. Presence of sand (gms/100 lit)	57 (40-70)	20 (10-31)	42 (30-60)
3. Head (feet)	11.5 (10.1-12.6)	10.4 (10.3-10.7)	17.8 (10.4-18.8)
4. Discharge (lit/Sec)	11 (9-12)	10 (7-12)	8 (2-10)
5. Diesel consumption (lit/hour)	0.95 (0.80-1.10)	1.01 (0.90-1.13)	1.08 (0.90-1.60)
6. Efficiency of pump (%)	37 (33-39)	29 (32-35)	31 (8-47)

Note: 1. Figures mentioned in item 2 to 6 are averages of respective minors.
2. Four tubewells in Madan Chapra and three in Shampur are filter wells and have no sand in their water.
3. Figures in parenthesis indicate range.

TABLE 8. **Water Conveyance methods.**

Particulars / Minors	Chakwa	Madan Chapra	Shampur	Study area
1. No. of owners	6	19	21	47
2. No.of owners used				
a.Unlined field channel	5	16	9	30
b.Unlined field channel and closed pipes	1	3	12	16
3. Closed pipe users				
a.Own pipe				
i. No. of owners			5	5
ii. Average length (feet) purchased			100	100
iii.Average total cost			590	590
b.Hired pipe (by buyers)				
i. No. of buyers	1	3	8	12
ii. Average length (feet) purchased	10	300	225	208
iii.Rental charges Rs/100 ft/day	10	10	10	10

efficiency (see table 7). Understanding the volume of conveyance losses through inventory data will help assess the need for closed pipes in some locations, either by water sellers or by buyers (see table 8). Some buyers lose as much as 30 to 50% of the amount paid for water rates in conveyance.

Economic Aspects

Keeping in mind the welfare of marginal and small farmers as a State objective, it is necessary to consider returns accruing over their investment made in groundwater extraction. This study found that northern Bihar experiences a severe shortage in electric power supply, with only one to two hours per day typically supplied. Diesel engines are nearly always used for pumping. While boring is cheap in this region, acquiring a diesel engine is costly for a marginal and small farmer. Therefore, the proportion of diesel engines to the number of borings is low. So diesel engines have been made to be mobile, with engines moving from one tubewell point to another, according to demand.

Growing demand for groundwater has provided an effective leverage to tubewell-cum-diesel engine owners to form "mini cartels." In their frequent but informal meetings, such owners agree to increase water selling prices, normally whenever the diesel cost rises, even if it rises only marginally (see table 9). Normally this increase is in a ratio (water price:diesel price) of 3 or 4 to 1. Sometimes it becomes 5 to 1, as it did in mid-1993. When the diesel rate increased by 50 paise per liter, the water selling rate shot up from Rs 20 to Rs 22 per liter. The buyers often have little recourse to competition in a limited market environment. The extent of water sellers and buyers is presented in Table 10.

TABLE 9. **Rise of diesel and water selling rates over time.**

Years \ Minors	Rate of diesel (Rs/Lt)	Rate of oil (Rs/Lt)	Water selling rates Rs/hour: Chakwa	Madan Chapra	Shampur
1975	1.68	8	10	-	-
1980	2.42	10-12	12	8	11
1982	3.41	15-16	13	10	12
1983	3.72	16	13	10	15
1984	3.71	17	13	10	15
1985	4.33	27	15	12	16
1989	5.36	28	18	15	18
1991	5.38	35	18	15	18
1992	6.52	41-42-51	20	20	20

Note : 1. Diesel and oil rates are collected from diesel pump station.
2. Water selling rates are based on memory recall by a group of farmers in respective minors.

TABLE 10. **Extent of water sellers and buyers in the study area.**

Particulars \ Minor	Chakwa	Madan Chapra	Shampur	Study Area
1. No. of				
a.Sellers	5	15	17	37
b.Buyers	25	79	82	186
2. Total area irrigated (acres)				
a.Sellers	5.84 (0.69-3.00)	32.56 (0.21-9.50)	34.76 (0.40-3.52)	73.16 (0.21-9.50)
b.Buyers	14.65	47.47	37.40	99.52
c.Total	20.49	80.03	72.16	172.68

Note:
a)Among 37 sellers, five have only tubewells. They rent-in diesel engine to irrigate their fields and also sell water.
b) Figures in parenthesis indicate range.

Left with no choice, the buyer pays the price demanded. The seller's diesel engine efficiencies vary from 20 to 65 percent (for 5 hp engines). The resultant effect in discharge is from 2 to 12 liters per second. Few sellers seem to realize that discharge levels are this low. We observed no efforts being made by sellers to improve efficiencies. Selling prices are standardized and not related to variable levels of efficiencies. The buyer pays the same rate (Rs. 20 per hour) irrespective of discharge levels. Distance between the engine location and the buyer's plot varies substantially. Conveyance losses in open field channels, vary from 20 to 50 percent.

Although the state government focuses on providing subsidies for pipes for boring, little attention is paid to distribution pipes to curtail conveyance losses. This study found that an average of one-third of all tubewell pipe lengths obtained with subsidies, was obtained in amounts more than required, based on local water tables. There is a tendency to sell the additional unneeded pipe lengths to others (see table 11).

Time and cost

How practical and beneficial can the Inventory approach be, for use by existing Water

TABLE 10A. **Number of hours diesel pumpset run-seasonwise in Chakwa minor.**

Season Minor	Kharif 1991	Rabi 91-92	Summer 1992	Kharif 1992	Total per annum
Chakwa					
a. Seller	168.00	164.75		138.75	332.75
b. Buyer	351.25	368.25		298.50	719.50
c. Total	519.25	533.00		437.25	1052.25

TABLE 11. **Details of tubewell pipes installed and sold (in feet)**

SN	Allotted	Installed	Sold
	Chakwa Minor		
1	40	70	70
2	90	60	30
3	80	20	60
	Madanchapra Minor		
1	117	57	60
2	100	60	40
3	80	60	20
4	80	50	30
5	80	50	30
6	80	50	30
7	80	30	50
8	80	20	60
9	80	60	20
10	80	60	20
11	80	50	30
12	80	60	20
13	80	50	30
14	80	60	20
15	80	50	30
16	80	60	20
17	80	30	50

Resources Department staff and canal irrigation officials, in collaboration with the farming community?

Given the experience of this Study Team in Bihar, we conclude that under present conditions, the proposed Groundwater Irrigation Inventory of average-size minor canal commands (300-400 ha) can be completed in about three to four days for the first time, and in about two days for subsequent annual inventories, depending on the size of the particular minor canal command. (This assumes that reasonably reliable village maps with landholding boundaries are available.) Inventory data can be collected with the assistance of the village level worker (Gram sevak) and the field operations staff of the Irrigation Department. The data could be processed at sub-division level for minors and distributaries and at division level for branch canals. Further, project-level data at the Chief Engineer's office and similarly, data of all projects in the State, could be processed at the Water Resources Department of the State.

Approximate costs of implementing the Groundwater Irrigation Inventory throughout the VCB are estimated as follows:

		Indian Rs.
A.	Field Data collection by key informants	
1)	For 27 minors @ Rs.50/day/person for 5 days per minor i.e., Rs.250/minor for 27 minors	6,750
2)	For 4 distributaries @ 5 minors per distributary 5 x 4 x 250	5,000
	Total A	11,750
B.	Data processing	
1)	Data processing could be done at two levels: Sub-division and Division lower level 3 man days x 4 Sub-Divi.=12 at higher level 3 man days = 3 i.e. 15 man days x Rs.50/day	750*

C.	Travel	3000
D.	Stationary	500
E.	Overheads	1000
	Total (A-E)	17000

* (This money could be given as an incentive to the existing staff rather than going for new recruits just for this exercise. Money could be paid on completion of the task (both A and B) at the end of season, as we did during our study.)

The data thus processed could be presented to higher-level officials of branch canals and to project-level officials in the Water Resources Department to enable more effective water management at the operational level and better planning at the policy level.

CONCLUSION

The obstacles to inter-departmental collaboration and cooperation with farmer representatives are challenging. However, it is hoped that greater awareness of wastage and problems brought on by lack of such integrated information and management, and the potential benefits to be gained from the Inventory will induce efforts to experiment with it.

At the end of this eight-month study, in a one-day state level workshop held in April 1993, the study findings were presented to top level officials and policy makers of the Bihar Water Resources Department. Officials attending the workshop were interested to extend the Inventory to other areas and recognized the potential for enhancing canal and groundwater irrigation management through integrating information from both sectors.

Participants expressed the value of an information base as a decision-support tool. Of particular concern was data on the increasing use of groundwater in canal systems, farmers' choice of using multiple sources of water, the potential role of water markets, and the importance of group tubewells, particularly for marginal and small farmers.

Preliminary application of the Groundwater Irrigation Inventory has indicated that it would be practical to supply the information base needed to do the following:

1) establish effective horizontal linkages between canal irrigation and minor or groundwater irrigation;

2) support necessary communication on resource use between farmers and the Water Resources Department;

3) support a macro-level management perspective for managing both surface and groundwater within a main canal system;

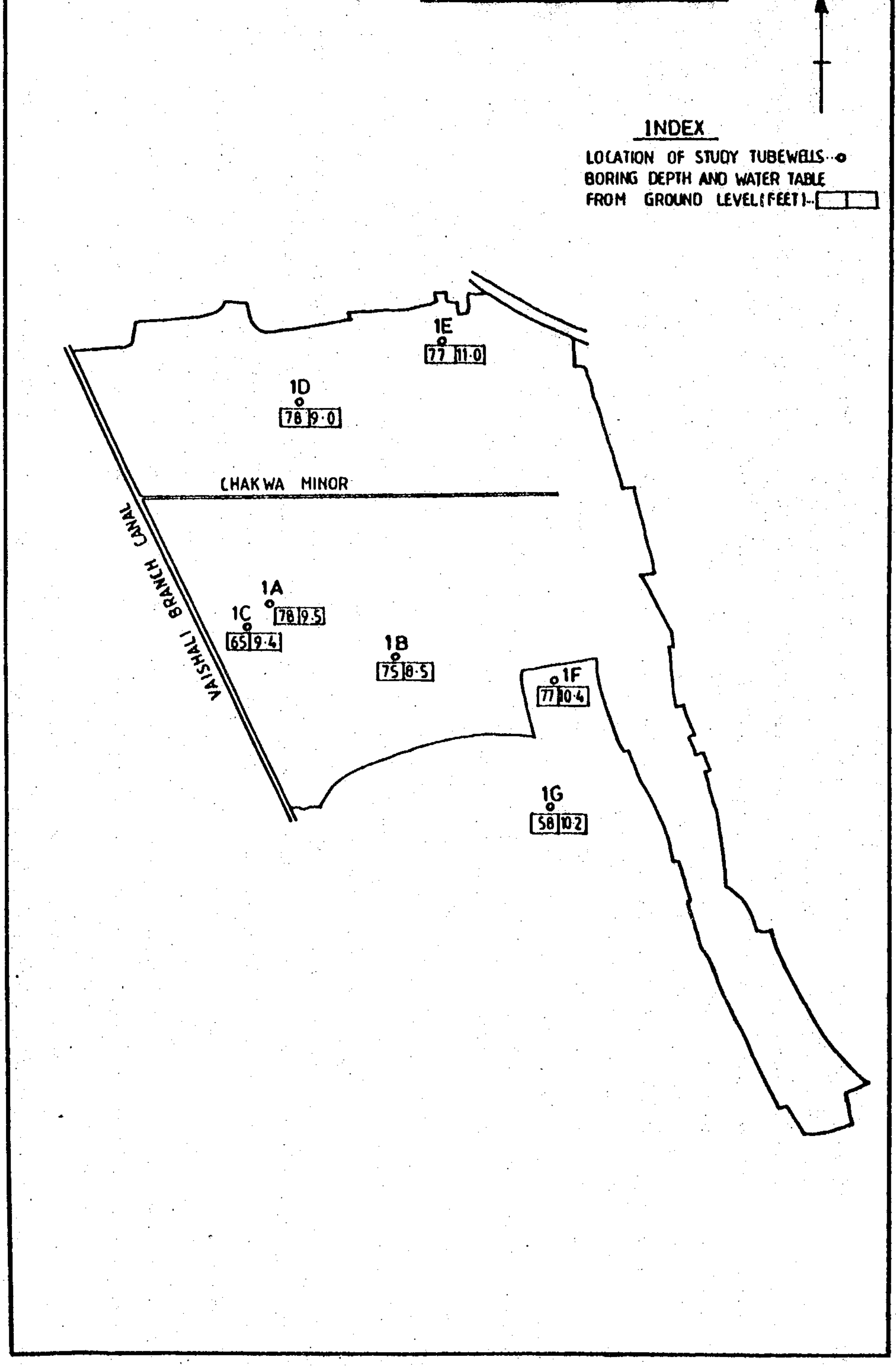
4) improve canal water distribution schedules and efficiency;

5) increase the returns on investments made from groundwater extraction by marginal and small farmers;

6) promote better understanding of improved methods of farming for utilizing multiple sources of water; and

7) enable various government or non-government agencies to promote groundwater development according to spatially rational patterns, sensitive to local resource conditions, rather than the present haphazard way generally followed.

Fig. 3 CHAKWA MINOR



Annex 1. DATA INCLUDED IN THE GROUNDWATER IRRIGATION INVENTORY

The following is a list of the types of information included in the Groundwater Irrigation Inventory.

A. Data at Level of Well/tubewell

1. Well/tubewell Identification
   - 1.1 Well/tubewell ID number
   - 1.2 Canal command location
   - 1.2.1 Minor
   - 1.2.2 Sub-Distributory
   - 1.2.3 Distributory
   - 1.2.4 Branch canal
   - 1.2.5 Project name
   - 1.3 Field ID number
   - 1.4 Name of Well/tubewell owner
   - 1.5 Administrative boundary
   - 1.5.1 Village
   - 1.5.2 Block
   - 1.5.3 District/Province

2. Types of Well/tubewell
   (In parentheses indicate depth in feet from ground level)
   - 2.1 Open dug well
   - 2.1.1 Dug well without masonry steining
   - 2.1.2 Dug well with masonry steining (either stone or brick)
   - 2.1.3 Dug well with boring

2.2 Tubewell
   - 2.2.1 Shallow tubewell (Depth 20 M to 40 M)
   - 2.2.2 Deep tubewells (Depth range 100 M and more)
   - 2.2.3 Bore wells : (Depth 20 M to 50 M)
   - 2.2.4 Bamboo tubewell

3. Design features of Well/tubewell
   - 3.1 Open boring
   - 3.2 Filter boring
   - 3.2.1 Length of filter pipe
   - 3.2.2 Length of blind pipe
   - 3.2.3 Packed with sand/gravel
   - 3.2.4 Diameter of pipe (inch)

4. Well/tubewell location is determined by:
   - 4.1 Water availability point
   - 4.2 Elevated point and suitable for gravity flow
   - 4.3 Central point of owner's field
   - 4.4 Close to more of buyer's fields
   - 4.5 Any other (specify)

5. Water Extraction Mechanism (WEM)
   - 5.1 Electric pumpset (h.p)
   - 5.2 Diesel engine (h.p)
   - 5.3 Animal Driven
   - 5.4 Manual
   - 5.5 Treddle pump
   - 5.6 Others (specify)

6. Type of well/tubewell Owner
   - 6.1 Private (irrespective of the type) Owned by individual farmers
   - 6.2 Group (irrespective of the type) Owned by a group of individual owner-farmers preferably with adjacent land-holdings.
   - 6.3 Public (also called state well/tubewell) Owned and operated by state government through its Minor Irrigation Department.
   - 6.4 Subsidized well/tubewell (Generally listed under private wells) Owned by individual farmers. (The investment cost on drilling & casing pipes has a subsidy component ranging from 33 to 90 percent distributed through Block Development Office. The sub sidy amount is based upon caste and land holding size, owned by the farmer.)

7. Who performs Installation, Operation and Maintenance
   - 7.1 Year of installation
   - 7.2 Installation was by whom
   - 7.3 Operation is by whom
   - 7.4 Maintenance is by whom

(Individual owner/farmer, farmer group, state agency, private development agency/NGO, other, combination)

8. Installation cost

Items	Date of installation		Purchase price	
	New	Second hand		If second hand present market rate for new one
1	2	3	4	5
8.1 Boring pipes				
8.2 Filter pipe				
8.3 Drilling cost				
8.4 Open well digging cost				
8.5 Diesel pumpset				
8.6 Electric pumpset				
8.7 Labor cost				
8.8 Any other (specify)				

9. Financial Source For Installation Investment
   9.1 Self financed
   9.2 Partial assistance by
   9.2.1 Neighbors
   9.2.2 Relatives
   9.2.3 Bank loan
   9.2.4 Government subsidy
   9.2.5 Non-government organization
   9.2.6 Cooperative societies

9.3 Full financial assistance from
   9.3.1 Government scheme
   9.3.2 Non-government organization

9.4 In case of group well, members
   9.4.1 Contribute equally
   9.4.2 Contribute proportional to land holding size

10. Tubewell Status
   10.1 Head (in feet)
   10.2 Trapping shallow/deep aquifer
   10.3 Estimated seasonal running hours
   10.4 Estimated seasonal discharge
   10.5 Present depth to groundwater table
   10.5.1 During Kharif
   10.5.2 During Hot weather

10.6 Estimated depth to groundwater table five years ago
   10.6.1 During Kharif
   10.6.2 During Hot weather

11. Operation and Maintenance cost of well/ tubewell
   11.1 Annual cost of
   11.1.1 Diesel
   11.1.2 Oil
   11.1.3 Electricity
   11.1.4 Maintenance including spare parts and repairs

12. Pumpset hours run per year

Season	For buyers' fields Area	For buyers' fields Hrs	For owner's fields Area	For owner's fields Hrs	Water selling rate Per Hour	Per Acre	Per crop Season	Hrs
	1	2	3	4	5	6	7	8
12.1 Kharif								
12.2 Rabi								
12.3 Hot weather								

13. Technical Performance of WEM (based on approximate averages by tubewell type/capacity)
   13.1 Estimated discharge (liters/sec)
   13.2 Estimated diesel consumption (liters/hour)
   13.3 Estimated power consumption (units/hour)

14. Availability and Suitability of Technology (based on categorical rankings from farmer group interview)
   14.1 Drilling equipment
   14.2 Pumps
   14.3 Motors (h.p)
   14.4 Accessories
   14.5 Distribution pipes
   14.5.1 Steel/rubber/PVC/other
   14.5.2 Length (feet)

15. Technology for Water Distribution
    15.1 Open Kutchha Channels
    15.2 Open Pucca Channels
    15.3 Underground pipes
    15.4 Partly underground & partly open channels
    15.5 Make-shift plastic/pvc pipes

16. Type of Water Use
    16.1 For use only on own farm
    16.2 For selling only
    16.3 Both for use on own farm and selling
    16.4 Group sharing
    16.5 Both for group sharing and selling

17. Criteria Used to Fix Water Selling Rates (If sold)
    17.1 Individual well Operational expenditure and marginal profit
    17.2 Group well Operational expenditure
    17.3 State Tubewell As per rates fixed by the Government

18. Local Water Selling Rates

19. Area Irrigated by Tubewell- seasonwise and cropwise

B. Data at Canal Command Level

20. Number of Wells/Tubewells within Command Area (separately for each hydraulic boundary)
    20.1 When tubewells first installed in area
    20.2 Approximate number of tubewells 10 years ago
    20.3 At present number of:
    20.3.1 Wells with diesel pumpset
    20.3.2 Wells with electric pumpset
    20.3.3 Tubewells with diesel pumpset
    20.3.4 Tubewells with electric pumpset
    20.3.5 Wells with electric and diesel pumpset

Methods \Source	Pvt. Tubewell (5 H.P.)	Group Well (5-7.5 H.P.)	State Tubewell (25 H.P)	Lift Irrigation (25 H.P)	Canal	
					Kharif	Rabi
Diesel/hour Electric/hour						
Per irrigation *Crops*(acre) Paddy Wheat Maize Vegetables Tobacco						
For any crop a) 1 irri/acre b) > 1 irr/acr						
Electric power tariff rates (Rs./HP/month)						

Fields\ Irrig.	Kharif 1 2 3 4 5	Rabi 1 2 3 4 5	Hot weather 1 2 3 4 5
Field Survey No. No.	Crop		
Owner's 1 2 3 Buyers 1 2 3			

20.3.6 Tubewells with electric and diesel pumpset

20.3.7 Wells with manual/animal driven lift

20.4 Number of tubewells functional at least once during last three seasons (Kharif, Rabi, Hot Season)

20.5 Number of tubewells defunct during at least last three seasons due to:

20.5.1 Machine defunct

20.5.2 Borewell defunct

20.5.3 Both machine & borewell are de funct

20.5.4 Water table has dropped too low for lifting

20.6 Number of other lift irrigation de vices

20.7 Number of other lift irrigation de vices functional at least once during last three seasons

21. Aggregate area irrigated only by groundwater
    21.1 Last Kharif season
    21.2 Last Rabi season
    21.3 Last Hot season

22. Aggregate area irrigated only by surface Ir-rigation
    22.1 Last Kharif season
    22.2 Last Rabi season
    22.3 Last Hot season

23. Aggregate area irrigated both by ground and surface Irrigation
    23.1 Last Kharif season
    23.2 Last Rabi season
    23.3 Last Hot season

24. Area where agriculture is adversely affected or made impossible by salinity (at any time during the year)

25. Area where agriculture is adversely affected or made impossible by waterlogging (at any time during the year)

26. Estimated average movement of groundwater table over last five years

Notes:

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[2] By conjunctive use of surface and groundwater, we mean that both sources are used on the same land during an agricultural season.

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