REPORT OF THE SURVEY TEAM
FOR
IRRIGATION FACILITIES IN ARRAH, THE STATE OF BIHAR, INDIA

JUNE 1972

OVERSEAS TECHNICAL COOPERATION AGENCY
THE GOVERNMENT OF JAPAN

インド ビハール州シャハバード地区かんがい農業調査報告書

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Foreword

It has been decided upon that the Agriculture Extension Centre, established in the State of Bihar as a link in the chain of the Indio-Japanese Technical Co-operation, should expand its activities taking a recent opportunity of extending the co-operation term.

The main purpose of this project is the wide spread of improved farming techniques into people through the rationalization of sub-centre facilities, especially of irrigation ones.

In close co-operation with experts in India, the Japanese Team surveyed the existing irrigation facilities from a farmer's point of view to make clear their cooperation with those under consideration for effective development of the whole programme.

As is widely known, India is one of the oldest and most advanced countries in the world in irrigation engineering, and its unique method and philosophical conception of irrigation have been attracting the admiration of the world.

The question here is whether the only fifty days of investigation (time for the actual field survey becomes shorter than that) is enough or not for the Japanese engineers to grasp the essense of the traditional agriculture supported by its own technical, social and economical backgrounds.

But we believe that the team could, at least, make the best use of the given time to grasp it thanks to the ready co-operation of engineers in India.

You may find some of our opinions and ideas in this report far from the truth, and others rather hard to realize, but we do hope that they will be taken into your flexible considerations on the principle of "technical co-operation".

In conclusion, we wish to express our heart-felt thanks to the authorities concerned in both countries for their warm assistance to our mission.

June, 1972

Hitoshi Fukuda
Leader of the Japanese
Survey Team

The Member List of the Survey Team for Irrigation Facilities in Arrah, the State of Bihar, India.

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Chapter I The Purpose of the Survey

The purpose of the survey was to examine the survey was to examine the posibility of securing constant and enough supply of irrigation water to the six sub-centres (have been called so, but characteristically should rather be called Extension Areas) scattered in the Shahabad District of Bihar, India, which have been developed by the Agricultural Extension Centre since 1968, and then to study how to sublimate the past activities into an impulse to organize the farmers in the community toward stabilized high productivity through generalization of the techniques introduced through the Centre.

All of these six sub-centres are located in the huge alluvial area between the Ganga and the Sone, and are irrigated from the river Sone through old facilities constructed in the latter half of the 19th century and a new modernistic barrage several miles up the river Sone built recently.

The main point of the survey, therefore, was the research into the posibility of developing irrigative efficiency of the exsisting facilities after grasping the present situation with the assistance of engineers in India. The idea of supplying subterranean water to those areas in which the orthodox way of irrigation is difficult, for example, was one of the results of the synthetic approaches adopted in order to seek for effective connection of the old irrigation facilities with new ones.

This kind of approach to be applied to the business of the sub-centres under the Agricultural Extension Centre, we believe, could also suggest the direction of the future project by India itself for improving the irrigative facilities in the area.

Chapter II The History of the Survey

The plan of the survey started when Mr. Uyama, the then Japanese Ambassador to India, talked with the chief minister of the State Government of Bihar about the necessity for consolidating the irrigative facilities as part of activities of the Agricultural Extension Centre in June, 1970. The main point of this talk was how to remove natural, social, and technical barriers to activities of the sub-centres for a better farming life, and especially how to secure reliable supply of water which is an indispensable key to effective popularization of the Centre's activities.

In October, 1970, OTCA dispatched Mr. Tadashi Sakamoto and Mr. Tetsuo Fukutomi to discuss the basic line of policy of the Centre after the extension of the co-operation term with the State Government. And the report of this conference also pointed out the necessity of utilizing subterranean water under the leadership of the sub-centres, as a result of the field survey carried out then.

In March, 1972, the Japanese Government received an official letter requesting the dispatch of experts in this field form the Indian Government.

Thus, cries for the utilization of subterranean water had been heard before this field survey started. As referred to in Chapter I, the Agricultural Extension Centre and the six sub-centres in the Shahabad District are all irritated from a barrage constructed by the loan from the World Bank through a large irrigation system. We, taking this into consideration, classified the area into several sub-areas according to the source of water, and then studied how to improve the present situation in answer to request we received from Mr. S. M. Shama, the Agricultural Secretary of the State Government of Bihar.

On the other hand, we made survey into the possibility of tube well to three sub-centres, Kulharia (Koilwar Block), Garhani (Charpokhari Block), and Katar (Piro Block) where we had to rely upon subterranean water because the exsisting irrigative facilities were of no practical use or unable to fill up immediate needs. The Japanses engineers in the Centre had also regarded these three sub-centres as the key positions of their future activities.

Besides the Central Government, we exchanged opinions with and collected data from the following authorities.

Mr. S. Hakim	Director of Agriculture Ministry of Food & Agriculture
Mr. S.K. Jain	Chairman, Central Water & Power Commission, Irrigation & Power Dept.
Mr. J.K. Jain	Joint Commissioner of Minor Irr. Agriculture Dept.
Mr. I.K. Mahajan	Secretary, International Commission on Irrigation and Drainage

In the State of Bihar, survey started with an exchange of views among the following Indian authorities and our resident experts, Mr. Chuji Miyasaka (Chief Adviser) and Mr. Shigetoshi Akita (Agricultural Extension).

Mr. S.N. Sharma	Agriculture Secretary
Dr. C. Thakur	Director of Extension
Mr. M. Prasad	Chief Engineer, Minor Irrigation Dept.

As a result of general survey into the relative facilities of the Agricultural Extension Centre and the six sub-centres since March 23 and the ensuing discussion, the basic line fo the survey was decided (see Chapter III), and presented to the State Government and the Central Government on March 30 just before our team leader left India.

Chapter III The Basic Line of the Survey

From ancient times the Ganga basin, especially the hilly districts on the right bank spreading into the gentle slope of cultivated area, has been offering the important source of irrigative water from its abundant subterranean water. The Shahabad District is one of these blessed districts, and it is very likely that the idea of pumping up such affluent groundwater may solve the problem of irrigation. However, the territory covered by the Agricultural Extension Centre has more than 100 years of experience in irrigation, and its facilities were improved in 1968 by the loan from the World Bank. On the other hand, some areas still remain unirrigated for some topographical reasons or other, or due to the lack of proper management of water supplying facilities.

In due consideration of this, and as a result of the general investigation, we decided the basic line of the surbey as follows.

1) In case additional irrigative facilities are necessary, we should make an exhaustive investigation into the existing facilities and try to improve them or make them more efficient before introducing new ones so as not to diminish total efficiency by leaving the old ones unimproved.

2) Irrigation should be managed keeping in close connection and co-operation with not only drainage but also other technical, social, and economical factors relating to the improvement of agriculture.

3) Indian experts and engineers should play the leading part to make the agricultural extension movement fruitful.

4) Proposed areas for utilizing subtrranean water should be classified into"Canal Area" and "Flooded Area" according to each irrigative characteristic before entering into an actual improvement plan. The study of the basic condition of subsidiary irrigation by subterranean water, therefore, should be made on the spot. (Details to be taken up here-inafter)

5) The idea of utilizing undergroundwater by tube well should be applied to both "Canal Area" (as a supplemental step to perfection) and "Flooded Area".

6) Flooded Area: The possibility of Closing "Ahar" System should be studied with a view to the effective utilization of tube wells and the protection of the whole area against floods by an low embankment.

7) Canal Area: Some measures should be taken to improve the existing irrigative facilities, especially village channels, or to make them more efficient, whie looking for the best way to link tube wells for effective irrigation.

8) Indian experts, the staff members of the Agricultural Extension Centre, and we Japanese survey Team have deliberated and agreed upon that we should give priority to the sub-centre near Koilwar (Flooded Area) and those in the Vicinity of Charpo-Kuhari and of Piro (Canal Area) before the rest under consideration.

Chapter IV Existing State of Shahabad District

4.1 General Condition of Agriculture

As shown in Fig. 4-1, Shahabad is a district situated in the northwestern part of the State of Bihar. General condition in this district is as shown in Table 4-1.

4.1.1 Rainfall and Temperature

Climograph of Shahabad district is shown in Fig. 4-2.

The climatic condition in the Bihar State divides the year into the following four seasons.

1) Southwest Monsoon Season: June 1 - September 30
2) Northeast Monsoon Season: October - December 31
3) Winter Period: January 1 - February 28
4) Hot Weather Period: March 1 - May 31

Monthly rainfall and monthly number of rainy days are shown in Table 4-2.

Table 4-1 Outline of Shahabad District

Item	Description	Remarks/2
1. Total geographical area by village papers	2,810,880 acres	1968-1969
2. Net area under cultivation	1,818,400 acres	1968-1969
3. Area irrigated	1,033,000 acres (57 %)/1	1968-1969
4. Area under principal crops		1968-1969
1) Rice	1,240,000 acres	
2) Wheat	655,000 acres	
3) Barley	36,000 acres	
4) Maize	55,000 acres	
5. Population		
1) Male	2,014,564	1971
2) Female	1,932,702	
3) Total	3,938,266	
4) Variation	+22.4 %	1961-1971
5) Density	897/mile^2	1971
6) Total workers	1,194,000	1971
7) Tiller	281,000	
8) Farm labor		

Remarks:

/1: Ratio of area irrigated to net area under cultivation

/2: Periods available for statistics.

Source: "Bihar Through Figures 1969", Bihar State

Table 4-2 RAINFALL (1901 - 1960)

PATNA

Season	Rainfall	Number of Rainy Days
1. South-west monsoon	(mm)	
June	125.4	
July	301.3	
August	341.4	
September	215.8	
Total	938.8	42.7
2. North-east monsoon		
October	49.7	
November	9.2	
December	5.5	
Total	54.4	3.3
3. Winter		
January	19.4	
February	24.4	
Total	44.2	3.5
4. Hot weather period		
March	9.5	
April	6.6	
May	14.7	
Total	30.8	2.7
5. Grand Total	1,129.9	52.2

Source: "Bihar Through Figures 1969", Bihar State "Annual Season and Crop Report", Bihar State.

Fig. 4-1 LOCATION MAP

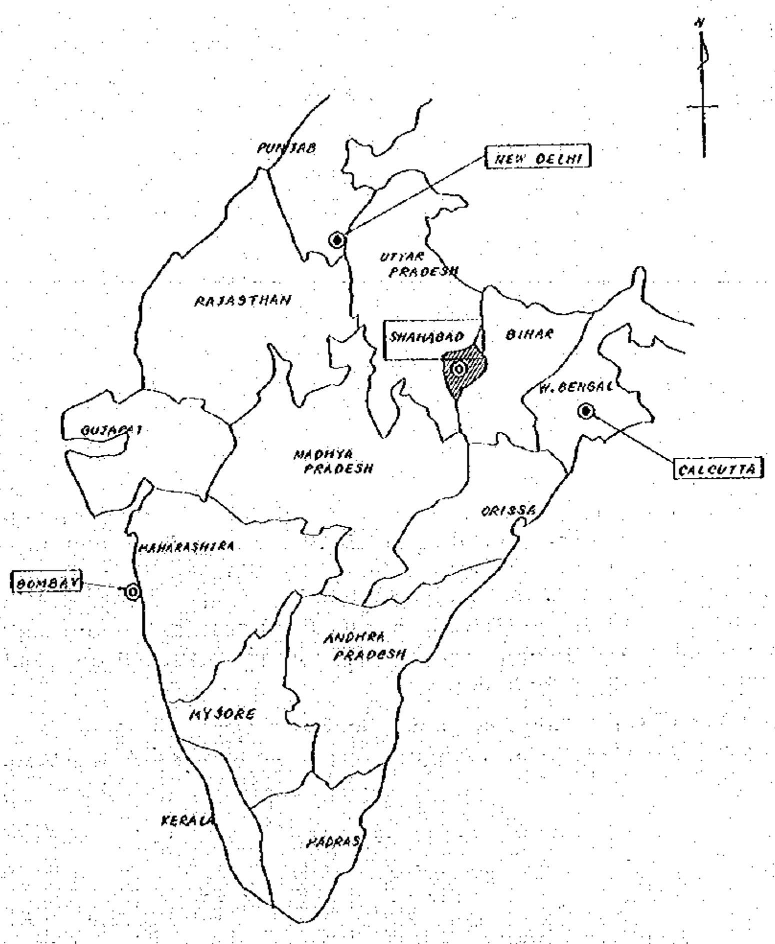
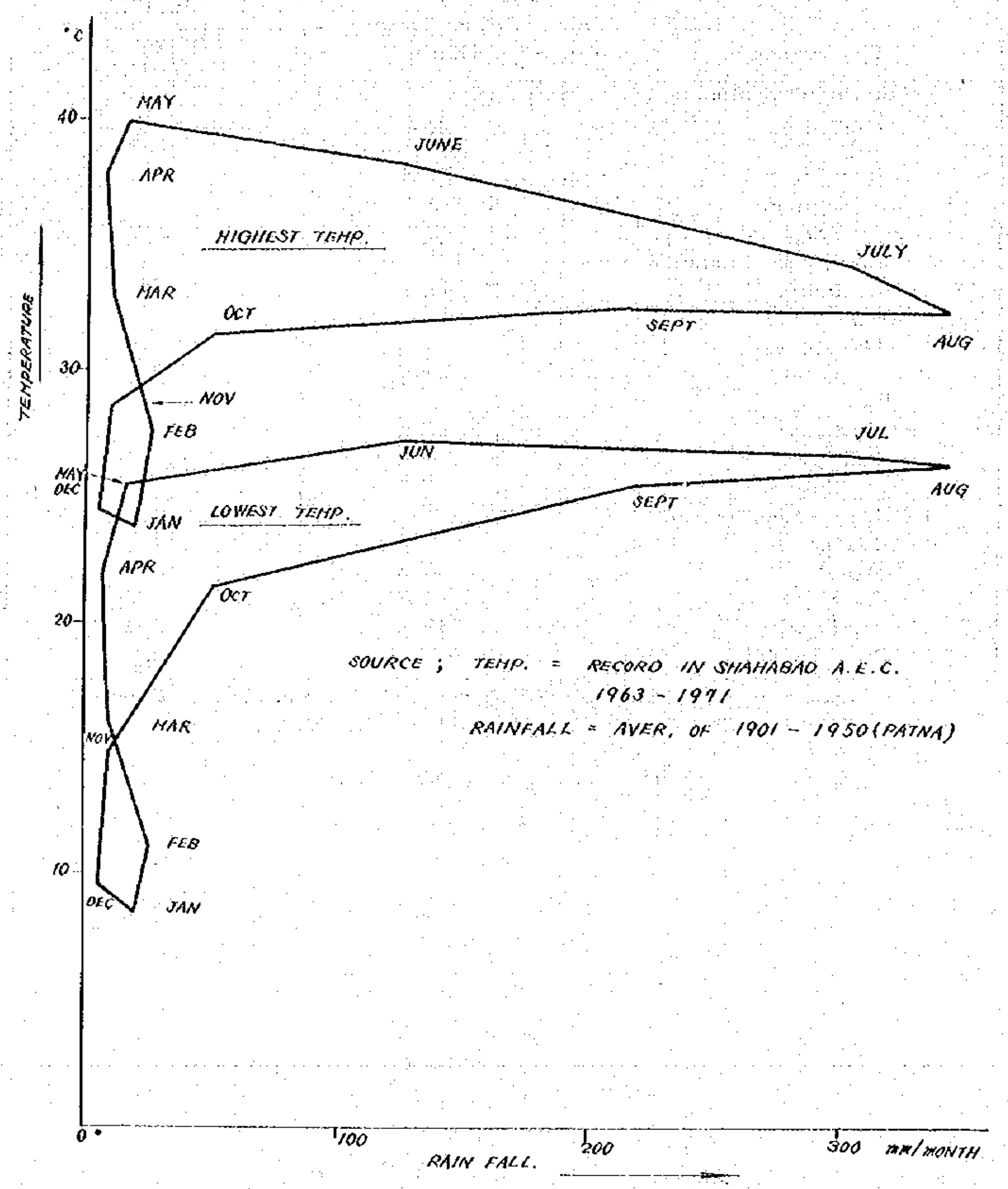


Fig. 4-2 CLIMOGRAPH



4. 1. 2 Crops and Cropping Periods

The cropping periods and major crops in this district are as shown below.

1) Kharif Period (mid-June to end of October): Paddy (high yielding variety)
2) Rabi Period (mid-October to end of March): Wheat
3) Summer Period (mid-March to end of June): Paddy

The period blessed with the southwest monsoon rainfall lasts from the end of the summer period to the middle of Karif period. During the remaining part of the year, artificial irrigation is required for grwoing crops.

4. 1. 3 Farmland Area, Irrigation Area and Planted Crops

Table 4-3 shows the acreage of farmland area, and Table 4-4 shows the irrigation area by crop.

Table 4-3 Acreage of Farmland Area

Unit: 1,000 acres

1. Total area by village papers	2,811
2. Land not available for cultivation	828
3. Culturable waste land	
1) Miscellaneous trees and groves	7
2) Permanent pasture and other grazing land	3
3) Culturable waste other than fallow land	14
4) Other fallow land	24
5) Current fallow	116
Total	164
4. Area sown	
1) Net area sown	1,818
2) Area sown more than once	944
Total Area Sown	2,762

Source: "Bihar through Figures 1969"

Table 4-4 ACREAGE IRRIGATED (1965 - 1966)

	Acreage	Remarks
	(acres)	
1. Canals	712,894	
1) Government canal	712,894	
2) Private canal	0	
2. Tanks	100,094	
3. Tube wells	56,143	
4. Other wells	34,069	
5. Other sources	261,305	
Total	1,164,505	
Crops	Acreage	Remarks
	(acres)	
1. Autumn rice	3,169	
2. Winter rice	1,121,272	
3. Summer rice	928	
4. Maize	103	
5. Wheat	254,958	
6. Barley	14,165	
7. Others		
Total	1,493,815	
Of the above,		
Food crops	1,493,875	
Non-food crops	2,940	

Source: "Annual Season and Crop Report" of Bihar State

4.1.4 Farmland Holding

Farmland holding per farm household is shown in Table 4-5. Average holding per farm household in Shahabad district is 7.17 acres (2.9 ha), and this figure is larger than the average in Bihar State which stands at 4.85 acres (1.76 ha).

Table 4-5 Ratio of Farmland Holding by Class

	Shahabad district	Bihar state
under 1, 0 acre	13, 15 %	21, 51 %
1, 0 - 2, 4	19, 43	26, 65
2, 5 - 4, 9	23, 02	23, 34
5, 0 - 7, 4	15, 81	12, 20
7, 5 - 9, 9	7, 64	5, 10
10, 0 - 12, 4	6, 13	3, 70
12, 5 - 14, 9	3, 42	1, 80
15, 0 - 29, 9	8, 46	4, 21
30, 0 - 49, 9	2, 21	1, 01
50, 0 -	0, 73	0, 48
Average	7, 17 ac	4, 85 ac

(Source: '71 Census.)

4.1.5 Administrative Organization and Agricultural Administrative Organization

Agricultural administrative organization is shown in Tables 4-6 to 4-8.

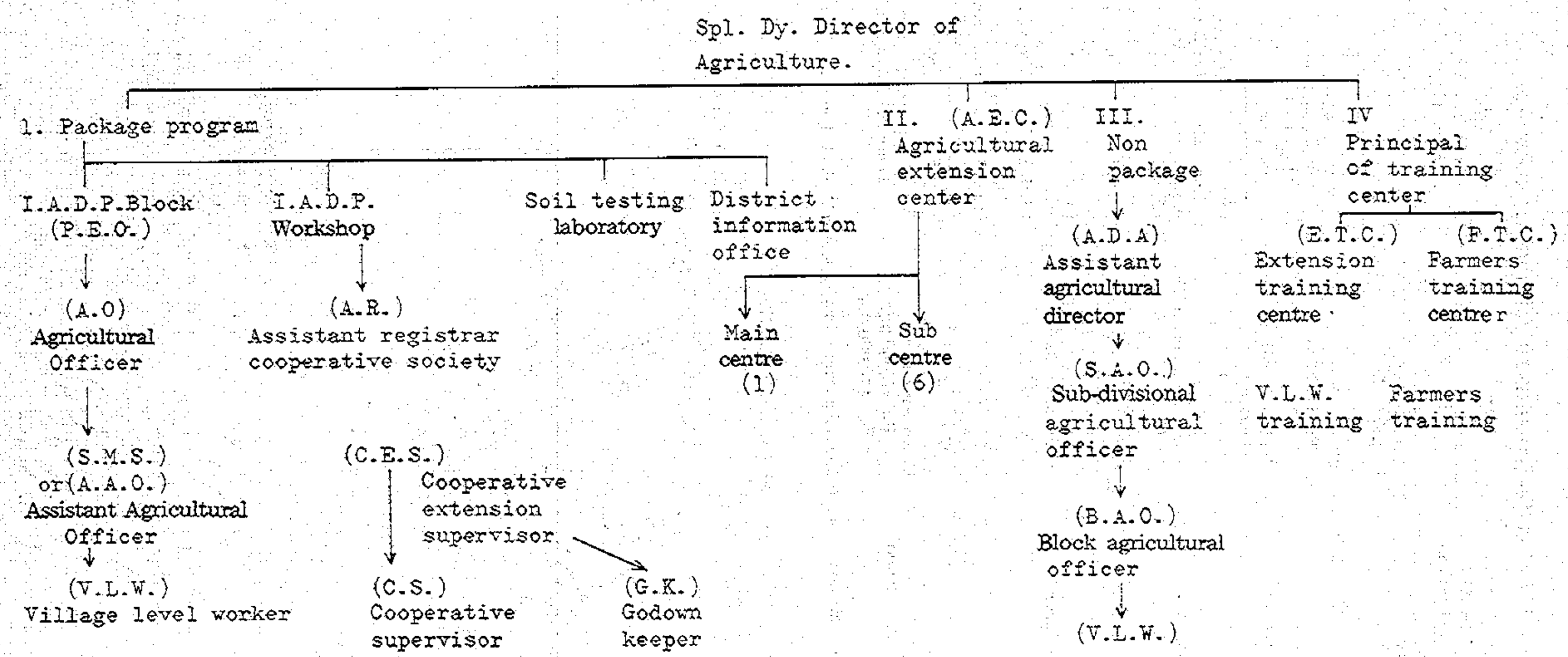
Table 4-6 Administrative Blocks

Shahabad district consists of the following sub-divisions and blocks.

a	b	c	d
Arrah Sub-division	Buxar Sub-division	Bikramganj Sub-division	Mohania Sub-division
1. Arrah	1. Buxar	1. Bikramganj	1. Mohania
2. Udvantnagar	2. Ranjpur	2. Karkat	2. Ramgarh
3. Koilwar	3. Itarhi	3. Dinara	3. Durgawati
4. Sandesh	4. Simri	4. Dawath	4. Kudra
5. Barhara	5. Dumraon	5. Kargahar	5. Bhabua
6. Shahpur	6. Nawanagar	6. Nokha	6. Bhagwanpur
7. Behea	7. Barhampur	7. Sasaram	7. Chainpur
8. Jagdispur		8. Sheosagar	8. Adhaura
9. Charpokhrri		9. Rohtas	9. Chand
10. Piro		10. Nawahatta	
11. Tarari		11. Chenari	
12. Sahar		12. Dehri	
		13. Nasrigaj	

Notes:
1. Underlined blocks are towns.
2. Number of police stations is 39.
3. Number of villages is 6,096, of which 4,757 are inhabited.
4. Number of Panchayats is 813.

Table 4-7 ORGANIZATION OF AGRICULTURAL ADMINISTRATION



Source: Shahabad A.E.C の宮坂理事長メモによる。

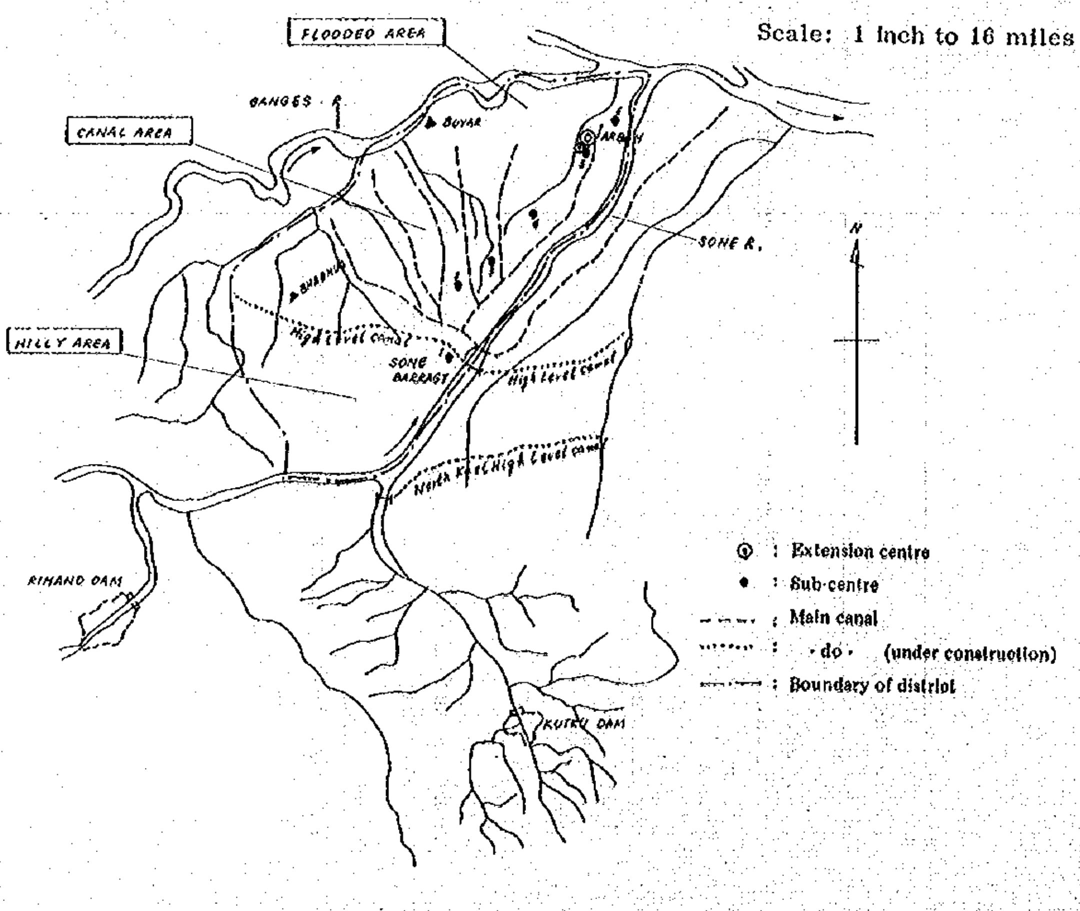
Table 4-8 IRRIGATION ADMINISTRATIVE ORGANIZATION

①	②	③	
Ministry of Irrigation	Ministry of Irrigation	Ministry of Agriculture	
River Valley Project Dept.	Irrigation Dept.	Irrigation Directorate Chief Engineer	
Chief Engineer	Chief Engineer	Lift Irrigation Dept (S.E.)	Minor Irrigation Dept (S.E.)
Superintending Engineer (S.E.)	Superintending Engineer (S.E.)	(E.E.)	(E.E.)
Executive Engineer (E.E.)	Executive Engineer (E.E.)	(A.E.)	(A.E.)
Assistant Engineer (A.E.)	Assistant Engineer (A.E.)	(S.O.)	(S.O.)
Sectional Officer (S.O.)	Sectional Officer (S.O.)	Petrol	Work Sarkar
Work Sarkar	Petrol	Operater	Mate
	Mate		
Construction cost: above Rs. 150,000,000	Costruction cost: Rs. 15,000,000 – Rs. 150,000,000	Construction cost: below Rs. 15,000,000	

Source: Memorandom of Miyasaka Project Manager, A.E.C., Shahabad

Fig. 4-3 SHAHABAD DISTRICT

Scale: 1 inch to 16 miles



4.2 Irrigation Conditions

4.2.1 Land Classification

As illustrated in Fig. 4-3, Shahabad district is divided into the following three areas.

1) Diara Area (Flooded area of the Ganga and the Sone)
2) Canal Area (Benefited area of Sone Canal System)
3) Hilly Area (Hilly area in the southern part of the district)

4.2.2 Relationship between Rainfall and Irrigation Water Requirement

Fig. 4-4 illustrates the relationship between irrigation water requirement and rainfall by cropping season. As will be clear from this figure, rainfall distribution is subject to substantial annual fluctuation which makes it impossible to transplant Kharif crops and impededs their growth seriously. As for water supply for cultivation of Rabi and summer crops, no desirable amount can be obtained as already mentioned unless artificial irrigation is conducted.

Fig. 4-4(1) RELATION BETWEEN GROWING CONDITION AND AMOUNT OF IRRIGATION WATER No. 1

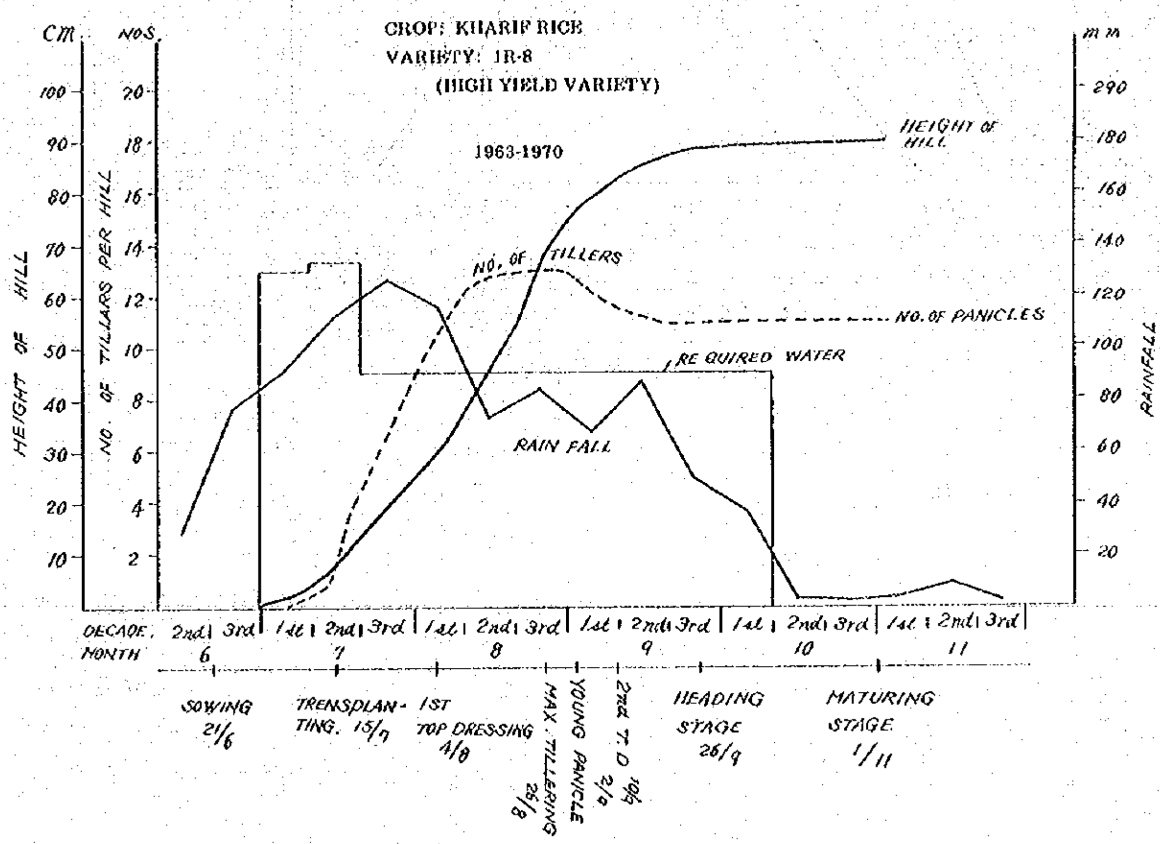


Fig. 4-4(2) RELATION BETWEEN GROWING CONDITION AND AMOUNT OF IRRIGATION WATER No. 2

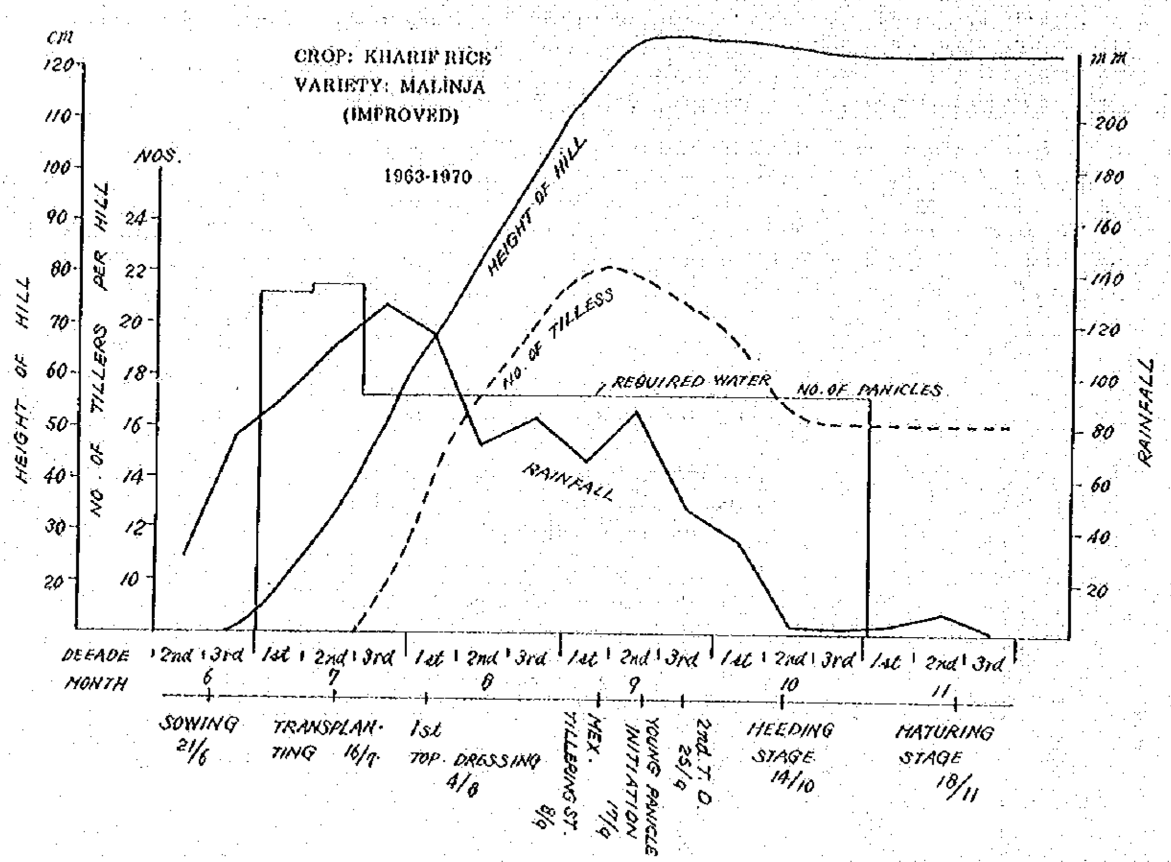


Fig. 4-4(3) RELATION BETWEEN GROWING CONDITION AND AMOUNT OF IRRIGATION WATER No. 3

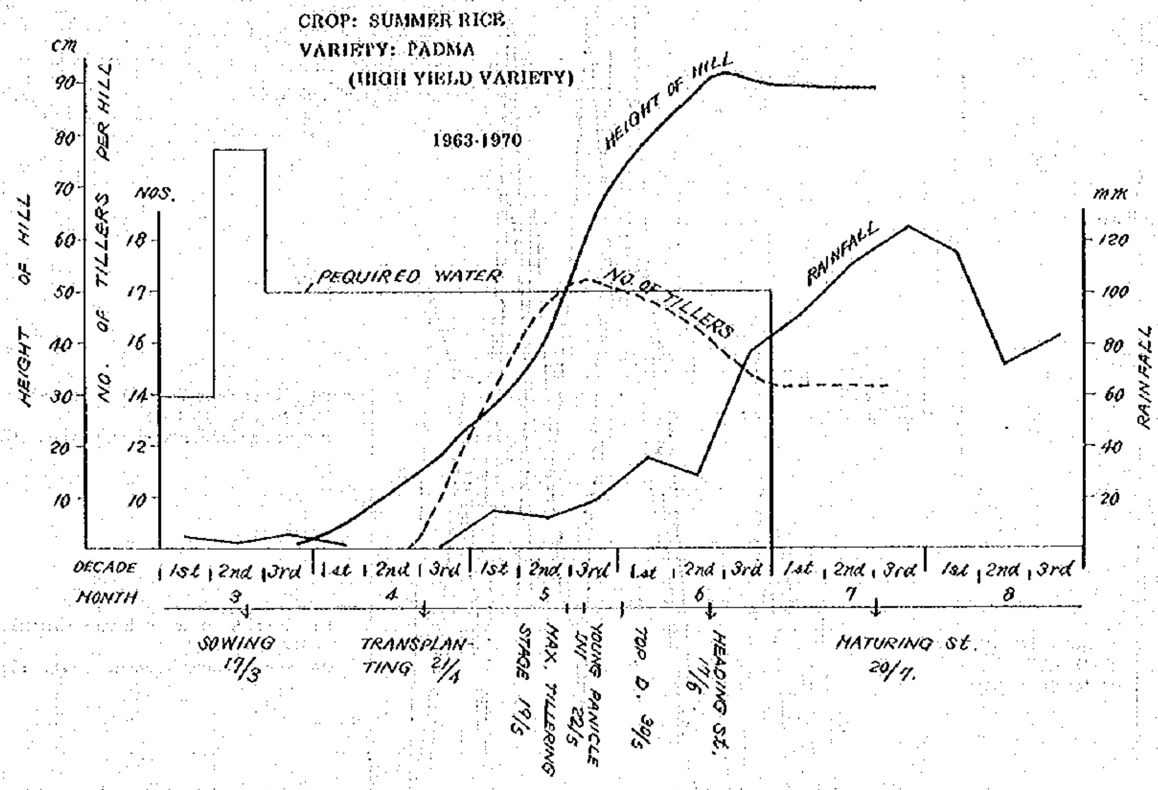


Fig. 4-4(4) RELATION BETWEEN GROWING CONDITION AND AMOUNT OF IRRIGATION WATER No. 4

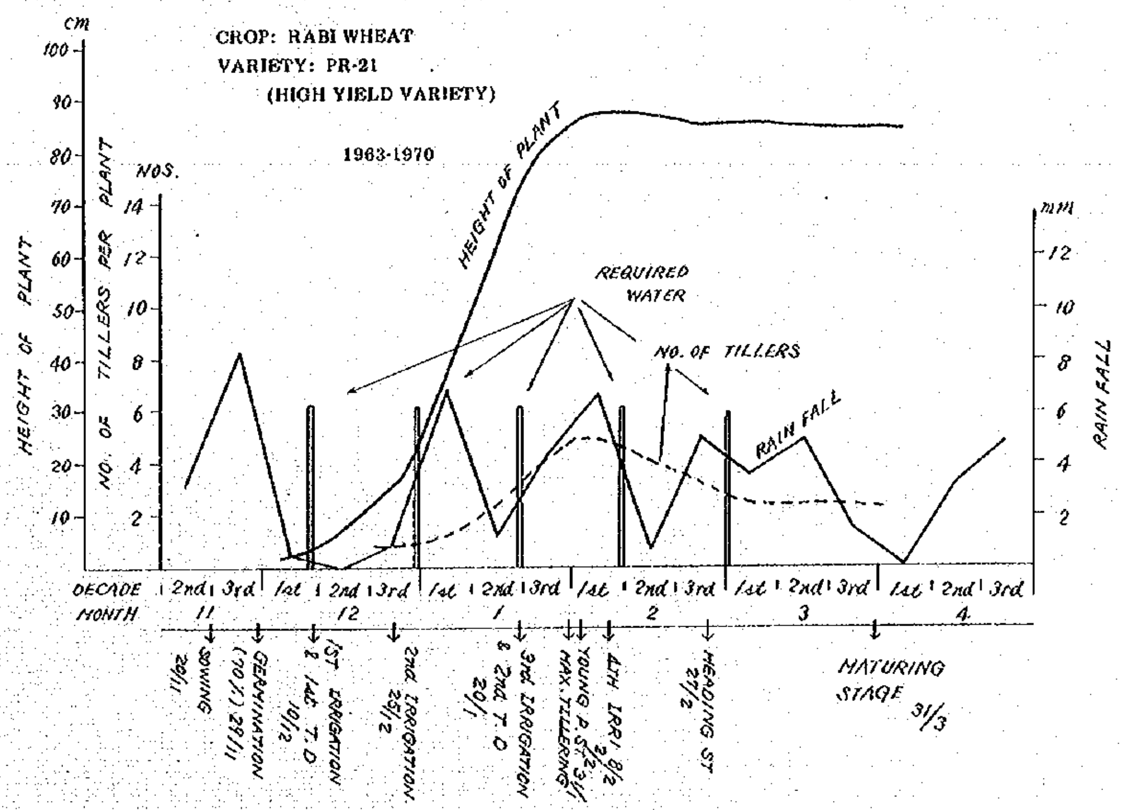


Fig. 4-5(1) RELATION BETWEEN ANNUAL RAINFALL AND AMOUNT OF IRRIGATION WATER REQUIRED No. 1

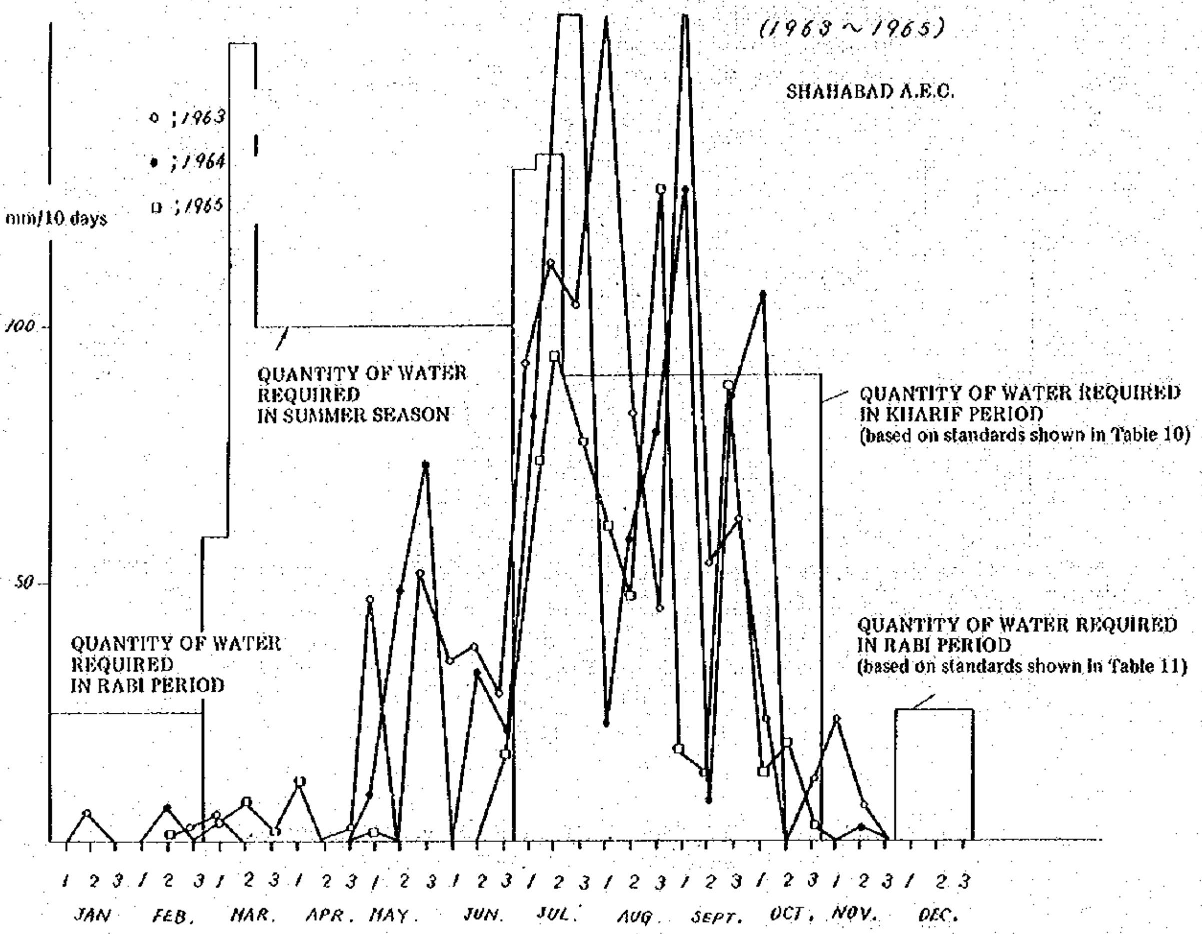


Fig. 4-5(2) RELATION BETWEEN ANNUAL RAINFALL AND AMOUNT OF IRRIGATION WATER REQUIRED No. 2

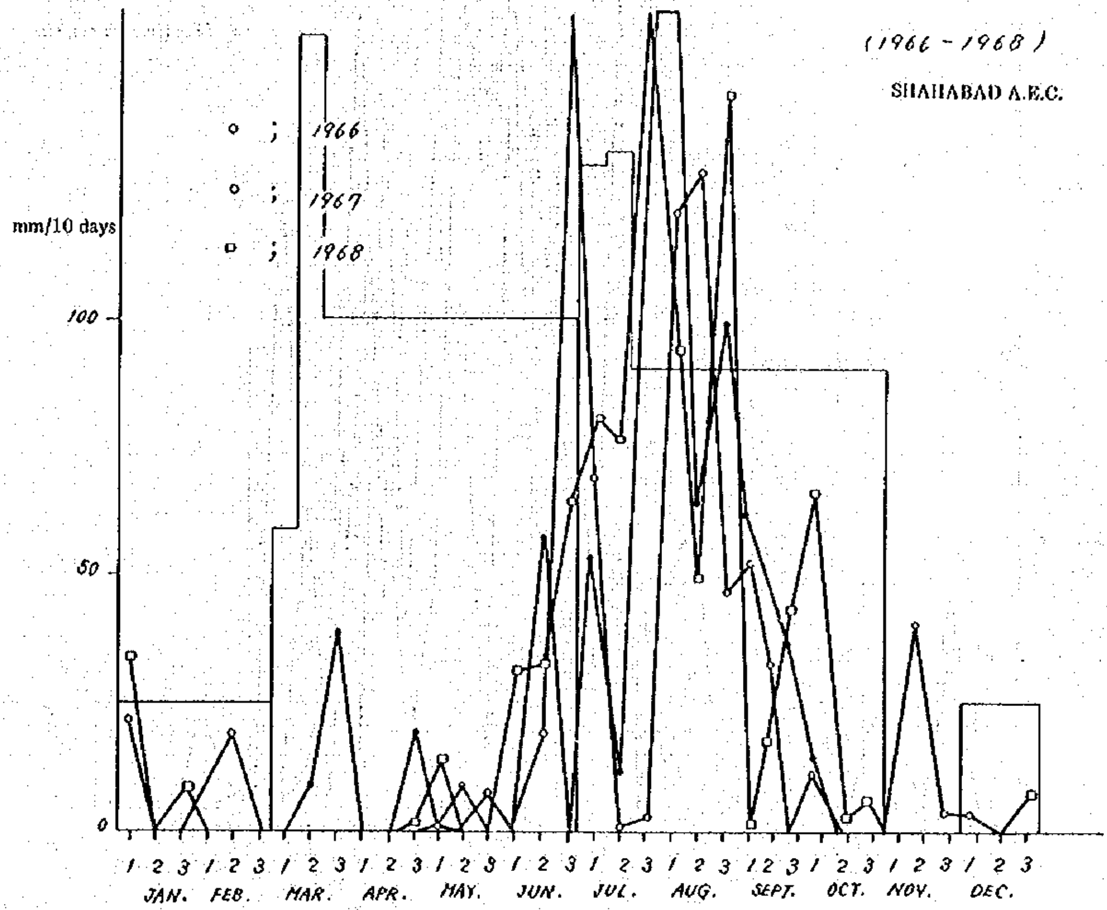
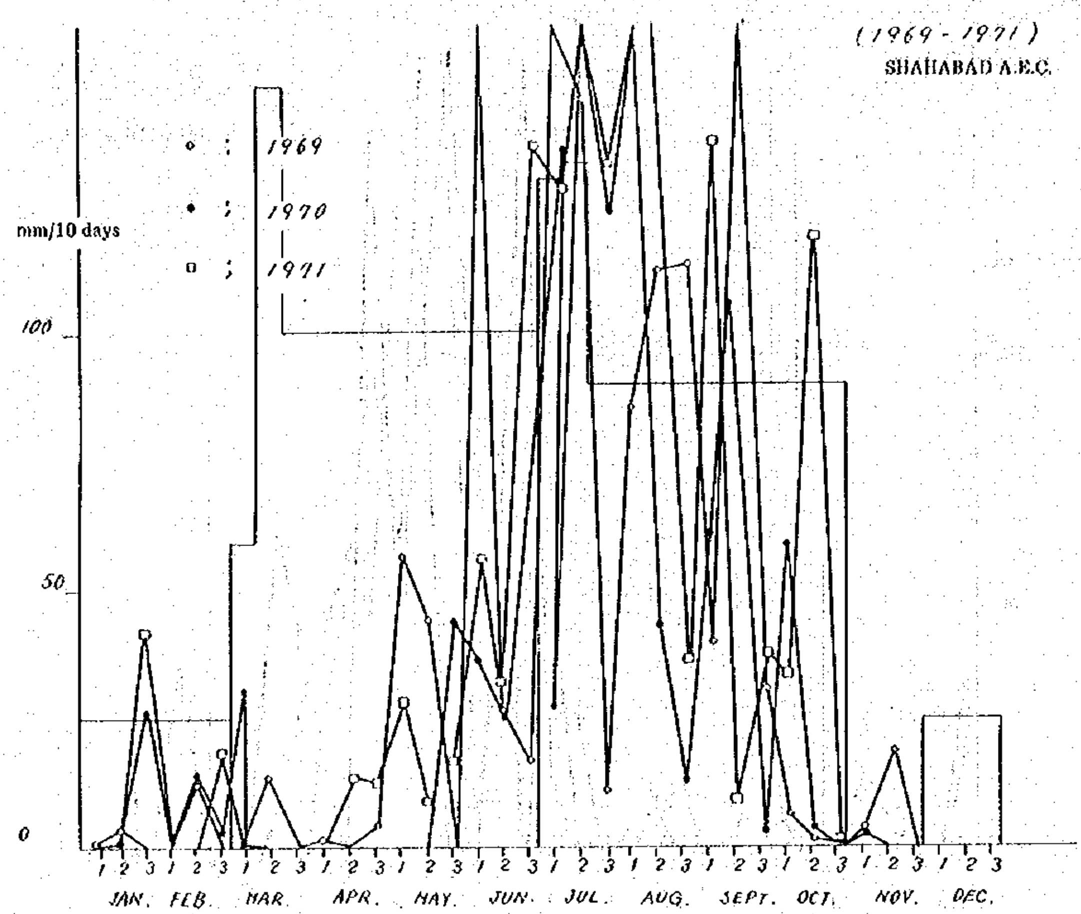


Fig. 4-5(3) RELATION BETWEEN ANNUAL RAINFALL AND AMOUNT OF IRRIGATION WATER REQUIRED No. 3



Water balance calculated from the annual rainfall is shown in Fig. 4-5. Of the years covered by this figure, 1966 was a drought year during which both rainfall and its distribution were both unfavourable.

Table 4-9 shows the comparative data covering the total water requirement, effective rainfall, irrigation water requirement and maximum availability of irrigation water by cropping season.

4.2.3 Irrigation Water Requirement

According to "Irrigation Engineering" by V. B. Priyani (published in 1955), the general irrigation water requirement in India is as shown in Table 10. Figures in this table are slightly larger than those shown in Table 11 which were given by Dr. H. M. Pandy of Rajendra Agricultural University in reply to the mission's inquiry on the water requirement in the State of Bihar.

Water requirement in depth for paddy is generally considered under three categories, i.e., evaporation, transpiration and percolation. Since water requirement data based on this classification are not available at present, studies made in this report are based on the data shown in Table 10.

Table 4-12 shows the design discharge including conveyance loss for each canal in Sone Canal System. The water requirement in depth obtainable from this table is substantially smaller than the standard values shown in Tables 4-10 and 4-11. The mission was unable to obtain the details of the calculation worked out for obtaining the figures in Table 4-12. These figures will be examined in Paragraph 5.3, Chapter V.

It is also to be added that no suitable measurement data are available on the canal permeability.

Table 4-9(1) CALCULATION OF IRRIGATION WATER REQUIREMENT
(Kharif rice: LR-8)

Month	Part	Event	Duty of water in depth (mm)	Rainfall (mm)	Effective rainfall (mm)	Water requirement (mm)	Remarks
Jun.	1st	Sowing; Jun. 21/1	/1	37.2	/2 27		
	2nd			28.8	18		
	3rd			77.2	67		
Jul.	1st	Transplanting; Jul. 15/1	130.0	91.6	81	49	
	2nd		133.0	112.8	102	31	
	3rd		90.0	125.9	115	0	
Aug.	1st	1st top dressing; Aug. 4/1	90.0	116.9	106	0	
	2nd		90.0	72.7	62	28	
	3rd	Max tillering; Aug. 26/1	90.0	82.8	72	18	
Sept.	1st	Young panicle initation; Sept. 2/1	90.0	67.6	57	33	
	2nd		90.0	86.7	76	14	
	3rd	Heading stage; Sept. 26/1	90.0	48.5	38	52	
Oct.	1st		90.0	36.7	33	[57]	Max.
	2nd			2.2	0		(matured
	3rd			2.5	0		in earlier
Nov.	1st	Maturing stage; Nov. 1/1		3.7			stege than that of
	2nd			8.5			Malinja)
	3rd			0.5			

Source: Based on the average data of observation conducted during the period of 1963-1970, and the technical standard prepared by Shahabad A. E. C.

/1: Based on the standard shown in Table 4-10

/2: Obtained by subtracting rainy days x 3mm/day.

Table 4-9(2) CALCULATION OF IRRIGATION WATER REQUIREMENT
(Kharif Rice: Malinja)

Month	Part	Event	Duty of water in depth (mm)	Rainfall (mm)	Effective rainfall (mm)	Water requirement (mm)	Remarks
Jun.	1st		/1	37.2	/2 27		
	2nd			28.8	18		
	3rd	Sowing; Jun. 21/1		77.2	67		
Jul.	1st		130.0	91.6	81	49	
	2nd	Transplanting; Jul. 16/1	133.0	112.2	102	31	
	3rd		90.0	125.9	115	0	
Aug.	1st	First top dressing; Aug. 4/1	90.0	116.9	106	0	
	2nd		90.0	72.7	62	28	
	3rd		90.0	82.8	72	18	
Sept.	1st	Max. tillering; Sept. 8/1	90.0	67.6	57	33	
	2nd	Young panicle initatiation; Sept. 17/1	90.0	86.7	76	14	
	3rd		90.0	48.5	38	52	
Oct.	1st		90.0	36.7	33	57	
	2nd	Heading stage; Oct. 14/1	90.0	3.2	0	[90]	Max.
	3rd		90.0	2.5	0	[90]	
Nov.	1st	Maturing stage; Nov. 18/1		3.7	0		
	2nd			8.5			
	3rd			0.5			

Source: Refer to Table 4-9(1) /1: -do-
/2: -do-

Table 4-9(3) CALCULATION OF IRRIGATION WATER REQUIREMENT
(rabi wheat: RR-21)

Month	Part	Event	Duty of weter in depth (mm)	Rainfall (mm)	Effective rainfall (mm)	Water requirement (mm)	Remarks
Nov.	1st	Sowing; Nov. 20/1	/1	3.7	/2		
	2nd	Germination; Nov. 29/1		8.5			
	3rd			0.5	0		
Dec.	1st		Dec. 10 62.5	0.5	0	62.5	Max.
	2nd			0	0		
	3rd		Dec. 31 62.5	0.9	0	62.5	
Jan.	1st		Jan. 20 62.5	6.9	3.9		
	2nd			1.2	0	58.6	
	3rd	Max. tillering; Jan. 31/1		4.4	1.4		
Feb.	1st	Young panicle initation; Feb. 2/1	Feb. 10 62.5	0	0	61.1	
	2nd			6.6	3.6		
	3rd			0.6	0		
Mar.	1st		Mar. 2 62.5	5.0	2.0	58.9	
	2nd	Maturing stage; Mar. 31/1		3.7	0.7		
	3rd			4.9	1.9		
Apr.	1st			1.5			
	2nd			0			
	3rd			3.3			

Source: Refer to Table 4-9(1)
/1: -do-
/2: -do-

Table 4-9(4) CALCULATION OF IRRIGATION WATER REQUIREMENT
(Summer rice: Padma)

Month	Part	Event	Duty of water in depth (mm)	Rainfall (mm)	Effective rainfall (mm)	Water requirement (mm)	Remarks
Mar.	1st	Sowing; Mar. 17/1	/1	0.5	/2 2.0		
	2nd			3.7	0.7		
	3rd			4.9	1.9		
Apr.	1st		59.0	1.5	0	59	
	2nd	Transplanting; Apr. 21/1	155.0	0	0	[155]	Max.
	3rd		100.0	3.3	0	100	
May	1st	Max. tillering; May 19/1	100.0	16.1	13.0	87	
	2nd		100.0	12.7	9.0	91	
	3rd	Young panicle initation; May 22/1	100.0	19.5	16.0	84	
Jun.	1st		100.0	37.2	27.0	73	
	2nd	Top dressing; May 30/1	100.0	28.8	18.0	82	
	3rd	Heading; Jun. 17/1	100.0	77.2	67.0	33	
Jul.	1st			91.6	81.0		
	2nd	Maturing stage; Jul. 20/1		112.88	102.0		
	3rd			125.9	115.0		

Source: Refer to Table 4-9(1)
/1: -do-
/2: -do-

Table 4-10 WATER REQUIREMENT IN DEPTH No. 1

Crops	Total Water Requirement	Normal Watering Interval	Avercage Water Requirement at Head of Main Canal
	(inches/120 days)	(days)	(acres/cusec)
1. Rice/1	48	10 - 12	40 - 45
2. Sugarcane	48		
3. Lucern	36		
4. Tobacco	30		
5. Garden fruits	24		
6. Cotton	20		
7. Vegetables	18		
8. Wheat	12	20 - 30	120 - 150
9. Maize	10		
10. Fodder crops (green oat)	9		

Remarks: /1: Refer to Table 4-12
Source: "Irrigation Engineering" by V. B. Priyani, 1955

For reference:

1. The following data are applied for the estimation.

	Water for puddling (mm)	Irrigation Water (mm)	Remarks (mm)
1st stage	100	30	130
2nd stage	50 (for 5 days)	35 mm (for 5 days)	133
		45 mm (for 5 days)	
3rd - 12th stage	0	10 x 90	10 x 90
Total	150	1, 013	1, 163

2. As for summer crops, 150 mm of water for puddling and 10 mm of daily water requirement in depth are applied.
3. Water requirement in depth in the puddling period is necessary only for a small area, Therefore, detailed description is ommited.

Table 4-11 DUTY OF WATER IN DEPTH No. 2

Crop	Duty of Water in Depth	
1. Kharif Rice		
1) Sowing to transplanting	10 inches/4 weeks	(8. 9 mm/day)
2) Puddling	6 inches	(150 mm)
3) Transplanting to Sept. 15	1. 5 inches/week	(5. 4 mm/day)
4) Sept. 15 to Oct. 15	6 inches/30 days	(5. 0 mm/day)
Total	46 inches	
Peak	0. 6 to 0. 6 inch/day (puddling)	(10 to 15 mm/day)
2. Summer Rice		
1) Sowing to transplanting	10 inches/4 weeks	(8. 9 mm/day)
2) Puddling	6 inches	(150 mm)
3) Transplanting to Jun. 30	3 inches/week	(10. 7 mm/day)
Total	65 inches	
Peak	0. 4 to 0. 6 inch/day	(10 to 15 mm/day)
3. Wheat		
1) Sowing to last watering	2. 5 inches/20-25 days	(2. 5 to 3. 1 mm/day)
Total	12 inches	
Peak	0. 1 to 0. 12 inch/day	(2. 5 to 3. 0 mm/day)

4. Winter Maize	
1) Sowing to last watering	2 inches/3 weeks (2.4 mm/day)
Total	12 inches/150 days
Peak	2 inches/3 weeks (2.4 mm/day)
5. Summer Maize	
1) 15 days after sowing	2 inches
2) up to last watering	2 inches/week (7.1 mm/day)
Total	30 inches/140 days
Peak	2 inches/week (7.1 mm/day)

Source: Explanation by Dr. H.N. Pandey, Rajendra Agricultural University, Patna, Bihar State.

Table 4-12 EXAMPLES OF DESIGN DISCHARGE BY CANAL
(Arrah Division)

	Commanding Area (acres)	Design Discharge (cusec)	Duty of Water (acres/cusec)
A. Dumraon branch canal	5,845	73	80
	4,440	55	81
1. Mahuary Dis.	2,850	31	92
2. Kesath Dis.	5,005	69	73
3. Waina Dis.	4,664	58	66
4. Jesary Dis.	2,217	28	79
5. Lathan Dis.	18,677	233	80
(6. Barauli Dis.	1,546	19	81)
(7. Jamorhi Dis.	2,651	33	80)
(8. Dhanupara Dis.	1,450	18	81)
(9. Itmah Dis.	260	3	87)
10. Karath Dis.	5,845	73	80
(11. Kesath 3 & 4	2,784	34	82)
12. Sikria Dis.	4,514	56	81
13. Baraon Dis	820	10	82
14. Raghunathpur Dis.	5,450	68	80
(15. Chaugain S Dis.	725	9	80)
(16. Bagen Dis.	2,625	33	80)
17. Ariaon Dis.	1,038	13	80
(18. Satsala Minor	641	10	64)
Total	61,365	767	80
B. Behea branch canal	13,143	161	82
19. Kurmurhi Dis.	8,629	120	69
(20. Pritampur S Dis.	641	9	71)
21. Sikraul Dis	2,745	43	64
22. Bihta Dis.	1,800	19	95
23. Gaharua Dis.	800	10	80
24. Tar Dis.	2,043	30	68
25. Kesary Dis.	1,700	25	68
26. Hetampur Dis.	3,810	58	66
(27. Chakwath Dis.	100	2	50)
(28. Garhani Dis.	5,830	80	73)
29. Kateya Dis.	15,990	222	72
(30. Gayanpur Dis.	1,445	22	66)
(31. Kakila S Dis.	1,420	22	65)
(32. Narainpur Dis.	2,040	33	62)
(33. Kateya Factory	675	11	61)
(34. Baraon Dis.	644	10	64)
(35. Udandih Minor	795	12	66)
Total	50,660	688	74
C. Arrah canal			
41. Rajpur Dis.	5,895	82	72
(42. Besaini Dis.	1,733	31	55)

(43.	Mangraulia Dis.	1,463	24	61)
44.	P. Channel, 1, 2, 3, 6, 9, & P. Channel l. d.	10,627	158	67
45.	Nasriganj Dis.	898	15	60
46.	Darihat Dis.	469	9	52
(47.	Darihat channel	400	7	57)
48.	Arrah Canal 0 mile to 16 mile and 26 mile to 48 mile	5,256	67	79
49.	P. Channel A, B, C, & 1, 2 from Dumraon branch canal	10,734	134	80
50.	P. Channel A & B from Behea branch canal	3,623	45	81
51.	Amauna Dis.	2,200	45	49
52.	Jajiwanpur Dis.	500	12	42
53.	Panmary Dis.	3,578	75	48
54.	Jaitpur Dis.	9,161	124	74
55.	Barauli minor from Behea branch canal	1,000	16	63
56.	P. Channel 4, 8, 10 & C.	8,400	121	69
57.	Kaithy Dis.	4,328	82	52
58.	Arrah Canal 17 mile to 26 mile	1,372	17	78
(59.	Deo Dis.	3,200	45	71)
60.	Mauna dis.	6,198	84	74
61.	Koilwar Dis.	4,687	74	66
(62.	Ekwary Dis.	3,028	33	92)
(63.	Maranpur Dis.	600	11	55)
(64.	Afzalpur Dis.	325	6	54)
65.	Dilia Narainpur Dis.	8,699	155	56
(66.	Pawar Dis.	2,500	40	63)
67.	Sakla Dis.	9,523	172	55
68.	P. Channel A, B, C, & 5, 7,	12,645	157	81
69.	P. Channel C. from Behea Branch Canal	3,370	45	75
70.	P. Channel D, E, F from Dumraon Branch Canal	5,725	73	78
71.	Koilwar Dis. 9 mile to end	5,845	73	80
(72.	Bansi Dehri Dist.	400	7	57)
(73.	Kori Dist.	2,027	30	76)
(74.	Banghi Minor Dist.	600	7	86)
75.	Belaur Dis.	2,626	38	69
76.	Bechiaon Dist.	4,000	55	73
77.	Asani Dist	4,500	60	75
78.	Chorain S. Dist.	1,400	22	64
79.	Dhanupra Dist.	1,000	16	63
(80.	Bhusahula Dist.	500	8	63)
81.	Chandwa Dist.	500	8	63
82.	Arrah Canal (Length: 48 to 52 miles)	500	8	63
(83.	Sarathua Link Channel	200	3	67)
	Total	139,261	2,042	68
	GRAND TOTAL	251,286	3,497	72

Remarks: Parenthesized number is conservatively estimated.

Notes: 1. 72 acres/cusec is equivalent to 8.4 mm/day, or a net duty of 6.4 mm/day if conveyance loss is assumed to be 30%. In other words, an irrigation capacity of 6.4 mm/day can be assured if actual discharge conforms to the design value.

2. Locations of canals are shown in Fig. 4-6.

Source: Data collected by Canal Department, Arrah Division.

At present, data on irrigation water requirement for Rabi wheat studied with respect to the change of soil moisture as well as the change of unit yield by the amount of irrigation water are not available. The mission's study on wheat will be based on Tables 4-10 and 4-11 because values shown in these tables are considered to have been empricially confirmed by many years of past cultivation practices.

Studies on summer paddy will likewise be based on the values shown in Table 4-10.

4.2.4 Irrigation Condition in Canal Area

(1) Sone Canal System was constructed in 1853 - 1874 by Lt. Dicken, an army engineer. Due to the superannuation of the headworks constructed at that time, the existing Sone Barrage was constructed in 1962 - 1968 with the necessary fund offered by IRBD. Sone Barrange is located 6 miles upstream of the old headworks. Sone Canal System has a total canal length of 1,757 miles, of which 28 miles is covered by the main canals, 329 miles by branch canals and 1,216 miles by distributaries. It commands an area of 17 lakh acres (6.8 lakh ha) streteching over the districts of Patna, Gaya and Shahabad. Except in areas embracing

Table 4-13 SONE RIVER DISCHARGE

Month		Discharge in Sone during pre-Rihand period at Dehri (75 per cent dependability)	Observed discharge at Dehri in post Rihand Dam period (75 per cent dependable)	Dependable Rihand release indicated in C.W.& P.C's report Bansagar
1	2	3	4	5
January	1-10	4,292 cusec	6,654 cusec	3,926 cusec
	11-20	4,199	5,807	3,984
	21-31	4,112	5,638	3,275
February	1-10	4,076	5,497	5,160
	11-20	4,051	5,573	5,022
	21-28	3,008	4,532	4,375
March	1-10	3,885	5,446	5,262
	11-20	3,045	5,158	5,000
	21-31	2,947	4,590	3,633
April	1-10	1,984	3,742	3,842
	11-20	1,831	4,595	5,313
	21-30	1,773	4,989	4,893
May	1-10	1,317	4,792	4,408
	11-20	1,226	4,969	5,488
	21-31	1,191	5,230	6,991
June	1-10	1,037	6,088	5,026
	11-20	1,095	7,184	4,684
	21-30	1,801	8,700	5,321
July	1-10	18,452	12,820	4,817
	11-20	26,132	12,323	3,575
	21-31	66,477	29,331	4,473
August	1-10	63,249	30,158	4,708
	11-20	1,18,579	32,713	3,162
	21-31	95,606	38,868	2,430
September	1-10	69,717	16,245	3,319
	11-20	1,18,579	18,640	2,948
	21-30	31,940	16,351	3,252
October	1-10	8,555	10,614	4,036
	11-20	3,482	9,748	3,061
	21-31	8,360	8,510	3,138
November	1-10	7,296	7,970	3,981
	11-20	5,531	6,872	3,103
	21-30	4,748	4,571	3,504
December	1-10	4,243	5,582	5,379
	11-20	3,906	8,227	4,623
	21-31	4,099	5,827	3,738

(Source; "Average effect of the processed Bansagar Project in Madhya Pradesh on irrigation schemes in Sone Valley, Bihar." Government of Bihar, 1971)

Table 4-14 WATER REQUIREMENT FOR IRRIGATION FROM SONE RIVER

Month	Existing Sone Canal	Sone High Level Canal	North Koel Canal	Total of Sone Canal system (2 + 3)	Total requirement (2 + 3 + 4)
1	2	3	4	5	6
	cusec	cusec	cusec	cusec	cusec
January	5,560	1,479	964	7,039	8,003
February	5,560	1,479	964	7,039	8,003
March	4,817	1,284	789	6,101	6,890
April	4,390	1,163	213	5,553	5,766
May	4,390	1,163	213	5,553	5,766
June	4,875	1,552	387	6,427	6,804
July	10,700	2,840	3,050	13,540	16,590
August	10,000	2,660	2,800	12,660	15,460
September	10,000	2,660	2,800	12,660	15,460
October	10,700	2,886	3,096	13,586	16,682
November	4,590	1,224	788	5,814	6,602
December	5,560	1,479	964	7,039	8,003
Total in acre-feet.	4,94,970	13,33,530	10,24,500		
	say 4.95	say 1.33	say 1.02		

(Source; "Average effect of the processed BANSAGAR Project in Madhya Pradesh on irrigation schemes in Sone Valley, Bihar." Government of Bihar, River valley project Dept. 1971)

strctures like drops, etc., all canals are earthern. As for the management of facilities, River Valley Project Department takes care of Sone Barrage, and Canal Department is in charge of the main canals and distributaries, whereas the management of village channels branching off from distributares is left to the hand of farmers.

(2) By the construction of Rihand Dam in the State of Uttar Pradesh on the upstream of the Sone river (1960 - 1964), the total Sone basin area of 26, 500 square miles was cut down by 20%, i. e., 5, 300 square miles, and the discharge of the Sone river declined. Table 4-13 shows the comparison of average discharges of the rivor before and after the dam construction.

The discharge is estimated to decrease futrher after completion of Bansagar Dam now under planning in the State of Mandhya Pradesh. For the abeyance of the Bansagar Dam construction plan, Bihar State is currently carrying negotiations with Madhya Pradesh State. Estimated discharge after completion of this dam is shown in Table 4-13.

(3) While the irrigation acreage currently covered by Sone Canal System is as indicated already, water requirement will be augmented to a large extent after the planned construction of Sone High Level Canal and North Koel Canal. Of these two new canals, the former has been under construction since 1969. Water requirement for irrigation from the Sone after completion of the two new canals is as shown in Table 4-14, and locations of the canals are shown in Fig. 4-6.

Table 4-15(1) SHORTAGE OF DISCHARGE IN WATER SOURCES OF SONE CANAL No. 1 (existing canal only)

Month		Discharge in Sone river	Required discharge in Sone canal (existingcanal)	Shortage
	1-10	6,654 cusec		0 cusec
Jan.	11-20	5,807	5,560 cusec	0
	21-31	5,638		0
	1-10	5,497		63
Feb.	11-20	5,573	5,560	0
	21-28	4,532		1,028
	1-10	5,446		0
Mar.	11-20	5,158	4,817	0
	21-31	4,590		227
	1-10	3,742		648
Apr.	11-20	4,595	4,390	0
	21-30	4,989		0
	1-10	4,792		0
May	11-20	4,969	4,390	0
	21-31	5,230		0
	1-10	6,088		0
Jun.	11-20	7,184	4,875	0
	21-30	8,700		0
	1-10	12,820		0
Jul.	11-20	12,323	10,700	0
	21-31	29,331		0
	1-10	30,158		0
Aug.	11-20	32,713	10,000	0
	21-31	38,868		0
	1-10	16,245		0
Sept.	11-20	18,640	10,000	0
	21-30	16,351		0
	1-10	10,614		86
Oct.	11-20	9,748	10,700	952
	21-31	8,510		2,190 MAX
	1-10	7,970		0
Nov.	11-20	6,872	4,590	0
	21-30	4,571		19
	1-10	5,582		0
Dec.	11-20	8,227	5,560	0
	21-31	5,827		0

(Source; "Average effect of the processed Bansagar Project in Madhya Pradesh on irrigation schemes in Sone Valley, Bihar." Government of Bihar, 1971)

Table 4-15(2) SHORTAGE OF DISCHARGE IN WATER SOURCES OF SONE CANAL No. 2
(Existing canal and Sone High Level Canal)

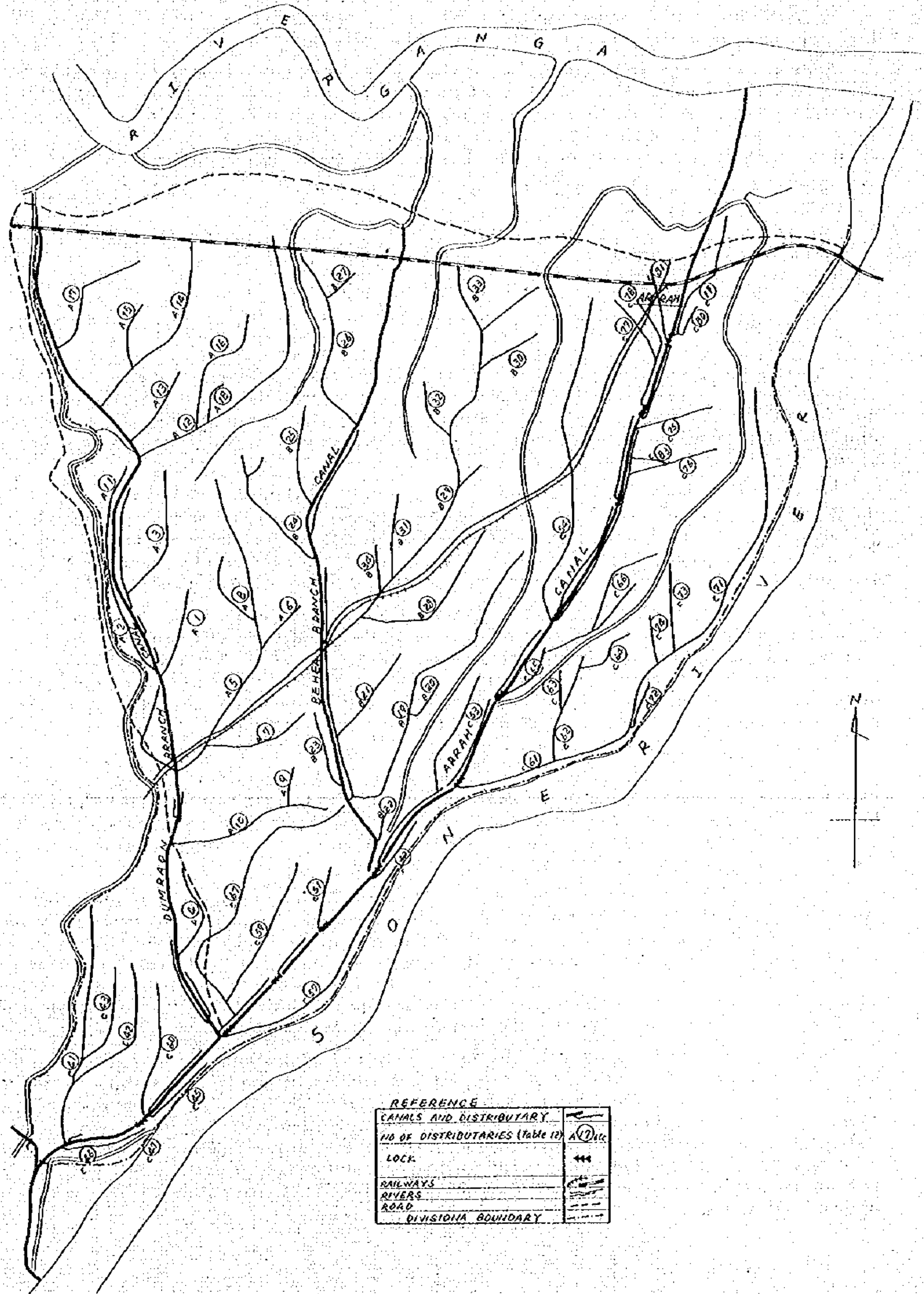
Month		Discharge in Sone river	Required discharge in Sone canal (existing +highlevel canal)	Shortage
	1-10	6,654 cusec	cusec	385 cusec
Jan.	11-20	5,807	7,039	1,232
	21-31	5,638		1,401
	1-10	5,497		1,542
Feb.	11-20	5,573	7,039	1,466
	21-28	4,532		2,507
	1-10	5,446		655
Mar.	11-20	5,158	6,101	943
	21-31	4,590		1,511
	1-10	3,742		1,811
Apr.	11-20	4,595	5,553	958
	21-30	4,989		564
	1-10	4,792		761
May	11-20	4,969	5,553	584
	21-31	5,230		273
	1-10	6,088		339
Jun.	11-20	7,184	6,427	0
	21-30	8,700		0
	1-10	12,800		740
Jul.	11-20	12,323	13,540	1,217
	21-31	29,331		0
	1-10	30,158		0
Aug.	11-20	32,713	12,660	0
	21-31	38,868		0
	1-10	16,245		0
Sept	11-20	18,640	12,660	0
	21-30	16,351		0
	1-10	10,614		2,972
Oct.	11-20	9,748	13,586	3,838
	21-31	8,510		5,076 MAX
	1-10	7,970		0
Nov.	11-20	6,872	5,814	0
	21-30	4,571		1,243
	1-10	5,582		1,457
Dec.	11-20	8,227	7,039	0
	21-31	5,827		1,212

(Source; "Average effect of the processed Bansagar Project on irrigation schemes in Sone Valley, Bihar." Government of Bihar, 1971.)

Table 4-15(3) SHORTAGE OF DISCHARGE IN WATER SOURCES OF SONE CANAL No. 3
(Existing canal. Sone High Level Canal and North Koel Canal)

Month		Discharge in Sone River	Required discharge in Sone canal (existing +Sone highlevel +North Koel)	Shortage
	1-10	6,654 cusec	cusec	1,349 cusec
Jan.	11-20	5,807	8,003	2,196
	21-31	5,638		2,365
	1-10	5,497		2,506
Feb.	11-20	5,573	8,003	2,430
	21-28	4,532		3,471
	1-10	5,446		1,444
Mar.	11-20	5,158	6,890	1,732
	21-31	4,590		2,300
	1-10	3,742		2,024
Apr.	11-20	4,595	5,766	1,171
	21-30	4,989		777
	1-10	4,792		974
May	11-20	4,969	5,766	797
	21-31	5,230		536
	1-10	6,088		716
Jun.	11-20	7,184	5,804	0
	21-30	8,700		0
	1-10	12,820		3,770
Jul.	11-20	12,323	16,590	4,267
	21-31	29,331		0
	1-10	30,158		0
Aug.	11-20	32,713	15,460	0
	21-31	38,868		0
	1-10	16,245		0
Sept.	11-20	18,640	15,460	0
	21-30	16,351		0
	1-10	10,614		6,068
Oct.	11-20	9,748	16,682	6,934
	21-31	8,510		8,172 MAX
	1-10	7,970		0
Nov.	11-20	6,872	6,602	0
	21-30	4,571		2,033
	1-10	5,582		2,421
Dec.	11-20	8,227	8,003	0
	21-31	5,827		2,176

Fig. 4-6 DISTRIBUTION OF SONE CANAL
(ARRAH DIVISION)



As a measure to meet this expected increase of water requirement and also cover the shortage ot discharge mentioned in Item (2) above, a new dam called Kutku Dam is planned to be construrted on the North Koel river, a tributary of the Sone. Completion of this dam, whose construction site is shown in Fig. 4-6, will bring solution for water shortage and at the same time make it possible to construct North Koel Canal.

Shortage of discharge in water source which will be observed when the irrigation area presently commanded by Sone Low Level Canal is expanded by the construction of Sone High Level Canal is shown in Table 4-15 assuming that the discharge of the Sone river will maintain the present level. Sone High Level Can is expected to be completed around 1974, while the completion of Kutku Dam and North Koel High Level Canal is scheduled for around 1977.

(4) Sone Canal System has a consistent order in which main canal branches into smaller canals as illustrated below.

Main Canal --- Branch Canal --- Distributary --- Sub-distributary or Minor Channel --- Village Channel

Canal distribution in Arrah Sub-division is shown in Fig. 4-6.

For diversion of water from the main to branch canal, the following method is usually adopted.

Firstly, the water level is kept at a fixed level by means of the control gate installed in the main canal. Then, the water gate in the branch canal installed about 100 m upstream of the control gate is operated for fine adjustment of its opening while watching the water level movement indicated by the water gauge. (A diversion rate of m^3/sec per gate can be applied for operation of water gates)

As will be descibed later, however, discharge in the main canal does'not usually satisfy the design value due to considerable sedimentation of sand which is also found in branch canals. The mission ofter noted that water gauges are installed at curved placed having an abnormal section by fixing poles on the canal bed with concrete blocks, so that elevation is not clear. Further, thers are some water gauges which are left without scale plate.

Diversion from the branch canal to the distributary is conducted in much the same way as described above. In other words, water level in the branch canal is raised at first, then water is taken in by opening the water gate. Water gate operation in this case is facilitated by the water gauge in the distributary (which is not installed in certain cases) and by the above-mentioned standard diversion rate per gate. Diversion into sub-disbutaries and village channels is carried out in almost the same way. Discharge records are available but their accuracy is highly doubtful.

Water diversion to village channels is conducted only by fully opening the water gate without raising the water level in the sub-bistributary. Petrol (Ref. Table 4-8) who occupies himself with the gate operation is informed of the design discharge in the canals. However, the structure of the existing gates and canals is not anything that permits accurate discharge measurement or adequate daily regulation of discharge rate.

Irrigation water is charged. Under a system called Satta, farmers apply for water distribution with the charge paid in advance. Therefore, the command area changes by year and by the number of applying farmers. The water charge varies by cropping season and is Rs 16 per acre in case of Rabi paddy and Rs 12 per acre in case of Rabi wheat. As shown in Table 16, the charge is slightly than 1 per cent of Rs 1,600 which is the gross teturn obtainable per acre from complete irrigation farming of improved, highyielding Kharif paddy such as IR-8, Malinja and others (production cost is approximately 35 per cent of gross return).

In spite of this established irrigation system, farmers entertain a strong suspicion that water may not be supplied at the right time. Reconnaissances and interviews made clear that there actually are some areas where water supply is either deficient or completely lacking. This is assigable to various causes such as unfair distribution in upstream areas, decline of water conveyance capacity, shortage of discharge of the Sone river, etc. At present, there exist no farmers' irrigation associations for management of tertiary canals. Hence, Petrol is allowed to exercise police power in prevention of illegal act like water seizure by farmers in upstream areas.

Table 4-16 IRRIGATION WATER CHARGE (1972)

Class of lease	Period	Nature of crops	No. of watering	Rate in Rs./Ac
I Kharif				
(a) Season lease	25 June to 25 Oct.	Paddy	Three times watering without limitation. Volumetric bases of supplying of water.	Rs. 16.00
(b) Other than Kharif lease (single watering)	Do	Paddy	Single watering without limitation.	Rs. 6.00
2, Rabi				
(a) Season lease	26 Oct. to 25 March	Wheat Barley Gram Peas, and food crops.	Two watering without limitation.	Rs. 12.00
(b) Other than Rabi season lease (Single watering)	Do	Wheat Barley	Single watering without limitation.	Rs. 7.00
(c) Rabi season lease	26 Oct. to 25 March	Early potato Double potato Late potato	4 waterings without limit. 9 waterings " 6 waterings "	Rs. 20.00 Rs. 34.00 Rs. 23.00
3, Hot weather				
(a) Hot weather season lease.	26 March to 24 June	Crops other than Suger cane	2 waterings 3 waterings	Rs. 12.00 Rs. 28.00
(b) Other than hot weather lease (Single watering)	Do	Crops other than suger cane Suger cane	Single watering Single watering	Rs. 8.00 Rs. 12.00
(c) Outside the hot weather season lease.	Do	Suger cane	Single watering	Rs. 12.00

Source: Lif Irrigation Dept.

Table 4-17(1) EXAMPLES OF IRRIGATION WATER BUDGET DURING KHARIF PERIOD (1969)

Variety: Malinja
Condition: Deep water irrigation

Period Part of month		① Water requirement in depth 1	Rainfall ② Total	Rainfall ③ Effective quantity	Shortage ④= 1 - 3	Irrigation plan ⑤ quantity supplied 2	Irrigation plan ⑥ Depth of water at and of season 3	Quantity of water passed through Cone Canal in 1966 ⑦ Arrah Canal At starting point 4	⑧ Dumraon Branch Canal At starting point 4	⑨ Behea Branch Canal At starting point 4	Growing condition	Remarks
		(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(cusec)(%)	(cusec)(%)	(cusec)(%)		
Jun.	1st		(0)	(0)	(0)	(0)	(0)	1,420 (41)	335 (44)	75 (11)		
	2nd		(19.2)	(9)	(0)	(0)	(0)	1,296 (37)	267 (35)	105 (15)		
	3rd		186.8	176	0	0	150	1,677 (45)	426 (56)	338 (49)	Seeding: Jun.21	
Jul.	1st	130	69.2	60	70	65	145	2,849 (82)	667 (87)	325 (47)	Puddling: Jun.21-Jul.15	Commencement of storage of rainfall water; permissible up to 150 mm in depth of water submerged
	2nd	133	40.4	30	103	65	50	2,309 (66)	622 (81)	344 (50)		
	3rd	90	2.7	0	90	65	15	2,724 (78)	686 (89)	496 (72)	Transplanting: Jul.16	
Aug.	1st	90	120.9	110	0	65	50	2,983 (85)	700 (91)	589 (86)		
	2nd	90	127.9	117	0	65	50	3,026 (87)	699 (91)	594 (86)		
	3rd	90	45.1	35	55	65	50	2,876 (82)	680 (89)	569 (83)	Max. tillering: Sept.8	Permissible up to 50 mm
Sept.	1st	90	52.4	42	48	65	67	2,742 (79)	745 (97)	550 (81)		
	2nd	90	32.1	22	68	65	64	2,743 (79)	672 (88)	572 (83)	Young panicle in initiation: Sept.17	
	3rd	90	0	0	90	65	39	2,832 (81)	665 (87)	571 (83)		
Oct.	1st	90	11.1	8	81	65	23	2,816 (81)	643 (84)	554 (81)		Permissible up to 150 mm
	2nd	90	0	0	90	65	-2	2,767 (80)	634 (83)	449 (65)	Heading: Oct.14	
	3rd	90	0	0	90	65	-27	2,738 (78)	637 (83)	507 (74)	Maturing: Nov.18	
Total		1,163		600	785	780						

Remarks:

/1: Calculated on the assumption that rainy day count 3 during the period of June to September, and 1 in October, and further, 3 mm per day are non-effective.

/2: Capacity of supplying water is estimated at 6.5 mm per day based on results of study on average capacity of supplying water of Sone Canal Shown in Table 4-13.

/3: Calculated by adding "(1-3) -5" to the figure of the preceding season.

/4: Design discharges for 7 -9 are 3,497, 767 and 688 cusee respectively. The parenthesized numbers are respective percentages compared with the above-said figures.

Table 4-17(2) EXAMPLES OF IRRIGATION WATER BUDGET DURING KHARIF PERIOD (1970)

Variety: Malinja
Condition: Deep Water irrigation

Period Part of month		① Water requirement in depth 1	Rainfall ② Total	Rainfall ③ Effective quantity	Shortage ④ = 1 - 3	Irrigation plan ⑤ quantity supplied 2	Irrigation plan ⑥ Depth of water at and of season 3	Quantity of water passed through Cone Canal in 1970: ⑦ Arrah Canal At starting point 4	⑧ Dumraon Branch Canal At starting point 4	⑨ Behea Branch Canal At starting point 4	Growing condition	Remarks
		(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(cusec)(%)	(cusec)(%)	(cusec)(%)		
Jun.	1st		(36. 5)	(26)	0	0	0	1, 739 (51)	365 (48)	378 (55)		
	2nd		(25. 3)	(15)	0	0	0	1, 201 (34)	378 (49)	221 (32)		
Jul.	3rd		137. 4	127	0	0	127	1, 879 (54)	533 (69)	291 (42)	Seeding: Jun.21	
Jul.	1st	130	27. 5	133	17	65	79	3, 065 (87)	605 (79)	576 (84)	Puddling: Jun.21-Jul.15	Commencement of storaging rainfall water; permissible up to 150 mm in depth of water submerged
	2nd	133	215. 3	205	0	0	50	2, 848 (82)	624 (81)	475 (69)		
	3rd	90	123. 3	113	0	0	50	3, 004 (86)	673 (88)	649 (94)	Transplanting: Jul.16	
Aug.	1st	90	187. 0	117	0	0	50	3, 298 (94)	740 (96)	658 (96)		
	2nd	90	43. 2	33	57	65	50	3, 192 (91)	670 (87)	607 (88)		
	3rd	90	12. 0	2	88	65	27	3, 330 (95)	761 (99)	628 (91)	Max. tillering: Sept.8	Permissible up to 50 mm
Sep.	1st	90	61. 8	51	39	65	53	2, 840 (81)	781(102)	606 (88)		
	2nd	90	106. 4	96	0	65	124	2, 794 (80)	508 (66)	485 (70)	Young panicle in initation: Sept.17	
	3rd	90	2. 8	0	90	65	99	2, 741 (78)	534 (70)	551 (80)		
Oct.	1st	90	59. 2	56	34	65	130	3, 469 (99)	745 (97)	578 (84)		Permissible up to 150 mm
	2nd	90	3. 6	0	90	65	105	3, 185 (91)	515 (67)	611 (89)	Heading: Oct.14	
	3rd	90	0	0	90	0	15	3, 224 (92)	703 (92)	642 (93)	Maturing: Nov.18	
Total		1, 163		877	601	520						

Remarks: Same as Table 4-17(1)

Table 4-17(3) EXAMPLES OF IRRIGATION WATER BUDGET DURING KHARIF PERIOD (1971)

Variety: Malinja
Condition: Deep Water irrigation

Period Part of month		① Water requir-ment in depth 1	Rainfall ② Total	③ Effec-tive quan-tity	Shortage ④ = 1 - 3	Irrigetion plan ⑤ quan-tity supn-lied 2	⑥ Depth of water at and of sea-son 3	Quantity of water passed through Cone Canal in 1971 ⑦ Arrah Canal At starting point 4	⑧ Dumraon Branch Canal At starting point 4	⑨ Behea Branch Canal At starting point 4	Growing condition	Remarks
		(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(cusec)(%)	(cusec)(%)	(cusec)(%)		
Jun.	1st		(56. 4)	(46)	(0)	(0)	(0)	1, 030 (29)	248 (32)	205 (30)		
	2nd		(31. 9)	(21)	(0)	(0)	(0)	832 (24)	136 (18)	112 (16)		
Jul.	3rd		(136. 3)	(126)	0	0	0	126	544 (71)	383 (56)	Seeding: Jun.21	
Jul.	1st	130	127. 1	117	13	0	113	2, 335 (67)	567 (74)	321 (47)	Pudding: Jun.21-Jul.15	Commencement of storaging rainfall water; permissible up to 150 mm in depth of water submerged
	2nd	133	173. 6	163	0	0	50	1, 577 (45)	370 (48)	291 (42)		
	3rd	190	132. 8	122	0	0	50	1, 621 (46)	550 (72)	136 (20)	Transplanting: Jul.16	
Aug.	1st	90	353. 7	353	0	0	50	1, 377 (39)	494 (64)	130 (19)		
	2nd	90	168. 1	158	0	0	50	937 (27)	207 (27)	90 (13)		
	3rd	90	36. 8	26	64	65	50	2, 037 (58)	459 (60)	360 (52)	Max. tillering: Sept.8	Permissible up to 50 mm
Sep.	1st	90	137. 2	127	0	65	147	2, 886 (83)	530 (69)	560 (81)		
	2nd	90	8. 3	0	90	65	122	2, 786 (79)	521 (68)	529 (77)	Young panicle in initation: Sept.17	
	3rd	90	37. 3	27	63	65	124	3, 445 (99)	698 (91)	664 (97)		
Oct.	1st	90	33. 3	30	60	65	129	3, 347 (96)	696 (91)	673 (98)		Permissible up to 150 mm
	2nd	90	118. 8	108	0	0	147	3, 354 (93)	689 (90)	679 (99)	Heading: Oct.14	
	3rd	90	0. 3	0	90	0	57	2, 082 (59)	449 (59)	267 (39)	Maturing: Nov.18	
Total		1, 163		1, 231	390	325						

Remarks: Same as Table 4-17(1)

(5) As seen in Tables 4-10 and 4-11, irrigation is conducted at intervals of 10 - 12 days in case of paddy and 20 - 25 days in case of wheat. Water distribution to respective distributaries is carried out continuous for 10 days for each 14 days as already described. Water is distributed under a rotation programme in which the watering date to each distributary is shifted suitably. This arrangement is necessitated chiefly by the increasing demand for water and is intended to cope with the following problems.

a) Canal section is required to be enlarged by a minimum of 14/10 as compared with the case of continuous watering.

b) If a fixed total amount of water is to be passed each each to a number of distributaries which are selected from among numerous distributaries for smooth rotation distribution (10 days' supply followed by 4 days' suspension), then the water mnagement will be made inevitably complicated (Amount of water required for each distributary varies by year and by the number of applying farmers, and this will add to the complexity of water management).

c) When the discharge of main canals drops, distributaries to which water is to be supplied at that time must suffer disadvantage.

Actual water supply condition is not clear because water is usually lacking in some areas, whereas it is generally or occasionally available in some other areas.

Ordinarily, water management within a village channel is carried out by farmers. Hence, one may imagine that water is supplied systematically to each village on the predetermined day day. This, however, is made impossible because the actual canal section has no such a capacity as will allow the supply of water for 10 to 12 days all at a time. From the interviews held with the farmers, the mission received the impression that each village channel is opened to receive 10 days' supply when water is available in the distributary and that water thus received is distributed to respective paddy fields in the predetermined order. But this impression cannot be substantiated by reason of the diversity of farmers' answers. It will be necessary to observe the actual water management condition for collection of accurate data.

(6) The Canal Department and farmers share the responsibility for the operation and management of canals. Government subsidy is not provided for farmers' operation and management of canals except in drought years or other special cases.

Water diversion from the canals under the control of the Canal Department has been totally suspended since April 2, 1972 for repair of facilities. The repair work was delayed because water demand kept on rising since the drought in 1966 what with the expansion of cropping acreage which was accelerated by the introduction of high yield varieties like IR-8 for summer cropping and what with the increase of irrigation area for Rabi wheat. By the breakage of facilities caused by the flood in 1972 and heavy silting, however, it became imperative to give up the 1972 summer cropping and effect the repair work. The mission's actual investigation revealed that a maximum of 0.5 to 1 m of silt is deposited in main canals, suggesting that sedimentation is in a serious state throughout the system. Further, the sectional view of canals prepared 100 years ago is now missing and it is doubtful whether this original section view can be reproduced or the section now required can be prepared. All the repair works ar are conducted by manual labour. The mission was informed that the management of village channels is conducted by farmers just before the Kharif cropping season. Judging from the lack of uniformity in the height of canal wall and many broken parts noticed during the survey, village channels do not seem to be under good management. At turnouts and intersections of canal and road, canal water levels with the adjacent wet land, so that a considerable loss is incurred. It is desirable that the water way be protected by rigid canal walls.

(7) Some state and private tube wells are found in the Canal Area. However, irrigation in this area depends basically on canals, and state tube wells are not fully utilized for reasons given in Paragraph 3.5.

4.2.5 Irrigation in Flooded Area

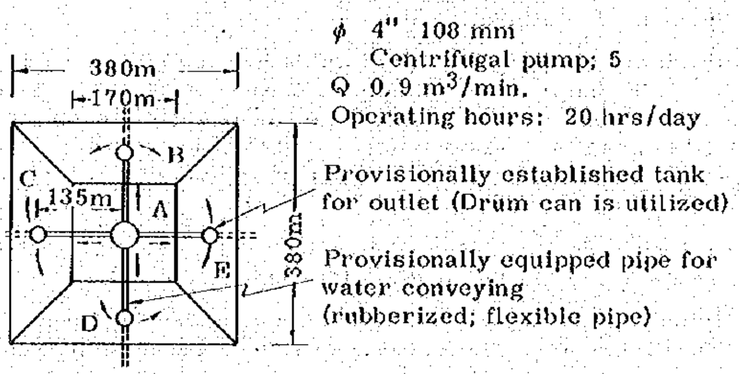
(1) Major water sources in this area are the state tube wells, private tube wells and flood water. The state tube wells are installed by the Lift Irrigation Department of the State Government and most of them have a pipe diameter of 9". There are some cases where water is pumped up from rivers. In most cases, state tube wells are annexed to brick-made or concrete-lined main canals.

With regard to private tube wells, many of them are 4"ϕ tube wells whose installation work is carried out either by the Minor Irrigation Department or entrusted in a lump deal to prviate contractors. There also are some open wells.

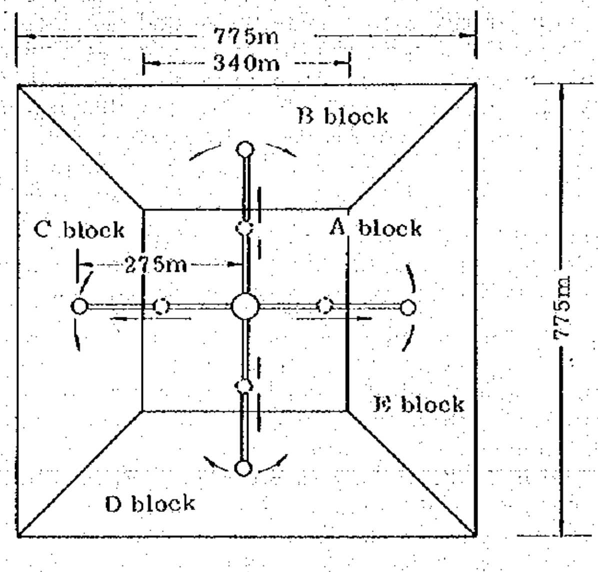
Number of tube wells and commanding acreage are shown in Table 802, and various structural factors of tube wells are shown in Fig. 4-7.

Fig 4-7 EXAMPLES OF TUBE WELL UTILIZATION PLAN

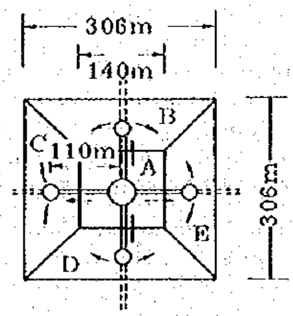
1. KHARIF CROPS
* Net area (A): 14.4 ha
36.6 acres
* Maximum daily water requirement: 7.5 mm



2. RABI CROPS
* Net area (A):
36.0 ha
90.0 acres
* Gross area (A) at planting rate 60 %:
60.0 ha
150 acres
* Maximum daily water requirement:
3.0 mm



3. SUMMER CROPS
* Net area (A): 9.4 ha
23.5 acres
* Maximum daily water requirement: 11 mm



(2) Flood occurs in the southwest monsoon season which lasts from June to September. Depth of flood water varies by area, but is usually about 1 m, and the current speed is slow. It is said that damage of paddy and properties and casualties due to flood are not serious in ordinary years. However, statistical data covering such damage or casualties are not

available. Flood comes from both the Ganga and the Sone.

Even in the Flooded Area, there are some lands where flood water does not reach in ordinary years. Such lands are found in the southern part where state tube wells are drilled concentrically. In areas not benefited by tube wells, water is obtained only from rainfall or from rainfall and flood. Flood occurs often during the period from August to the beginning of September. In this period, paddy has a height of 110 - 120 cm (in case of improved variety) and is therefore little subject to submersion, but suffers damage of fall and washing-away. Occasionally, transplanting is delayed due to decomposition of seedlings caused by the flood during the nursing period (June). 1971 recorded an exceptionally serious flood which incurred a loss amounting to as much as approximately Rs 80,000,000 in Shahabad district alone.

In areas where flood is the only water source, irrigation water cannot be obtained until the end of October after the flood season is over, and in years of little rain, water for nursery and soil puddling often falls short of demand. Despite the prevalence of such unstable irrigation condition, Kharif paddy is cultivated in almost the entire Flooded Area. In this area, short-statured varieties like IR-8 are not introduced. However, since improved varieties like Malinja and Masuri are already grown, special variety like floating paddy need not be introduced.

(3) As in the case of canals, farmers are not satisfied with water distribution from tube wells and state that "water is not supplied at the right time". This is a ttributable mainly to the delay of operation commencement and machine trouble caused by frequent power stoppage, delay of business procedure and insufficient communication.

Tube wells cover the respective design commanding areas, and farmers who occupy parts of the commanding area respectively apply for irrigation water in the beginning of cropping season. Water charge is paid in advance. Water is supplied three times for Rs. 16/acre paid for Kharif crops, two times for Rs. 12/acre paid for Rabi crops and two times also for Rs. 12/acre paid for summer crops. Even though water is not supplied timely, water charge is not repaid. State tube well drilling work is not based on farmers' requests, but is carried out in accordance with a schedule prepared by the Lift Irrigation Department.

In the case of Well No. 10 in Kulharia Sub-centre, depth of tube well is approximately 32 m and groundwater level is approximately 3 m as shown in Table 8-2. As for the pump, *there are many kinds such as bore hole pump, centrifugal pump, etc. in addition to* ϕ 12" -submerged water pump (300 mm in diameter). Machines are ordinarily domestic-made. Electric power is 3 phased, 440 volts and alternating current. Due to the low daytime voltage, machine operation is often carried out at night. Even though any trouble happens the operator belonging to the Lift Irrigation Department only reports it and does not repair it himself. For this reason, operation is often suspended for a long time once a fault develops. How machines are actually put in operation.

1: Telephone network for conveying operation orders is not established, nor is vehicle service for maintaining close and constant communication available is not known due to lack of correct data. In order to grasp the actual condition, there will be no choice but to resort to the observation and data collection by some competent persons like resident Japanese experts. In this area, water is drawn not only from tube wells but also pumped up from rivers. A tube well with 6" ϕ (300 mm) is capable of pumping up 0.03-0.05 m^3/sec of water which can cover, as shown in Table 8-8, a cultivation acreage of 60-150 acres for Kharif crops, 100-175 acres for Rabi crops, and 10-50 acres for summer crops.

(4) Private tube well drilling is carried out by the Minor Irrigation Department as works based on farmers' requests. Just as in the case of state tube wells, operation of private tube wells is impeded by power stoppage. Major troubles are the clogging of filter due to silt, deposit of lime, etc., and overheating of induction coil in motor due to immoderate operation at time of voltage drop. The mission learned that repair is effected quickly in case of wells owned by farmers. Though private tube wells seem to be less subject to operation suspension than state tube wells, no details are known about their operation condition. Surplus water is supplied to other farmers's land in the surrounding area against collection of charge.

Daily operation hours is approximately 3-4 hours in cases of Kharif and Rabi crops. Due partly to power stoppage, private tube wells cannot be said to be operated at full capacity. In the flooded area, depth of tube well is approximately 50-70 m and groundwater level is approximately 3 m below the ground surface in many cases. Pumps are mostly centrifugal type with ϕ 4" (equivalent 100 mm). Though there are some open wells equipped with a centrifugal pump, most of them are operated intermittently because water ceases to flow out after some time of operation.

Reference

The tube well drilling cost is shown in Reference Data 2. Goverment subsidy is provided to cover 25 per cent of the cost so that the remainder must be borne by farmers themselves. To cover this 75% portion of the cost, loans are advanced by the Land Mortgage Bank at an annual interest rate of 9 per cent. A part of the fund obtainable from this bank should be deposited at time of application.

According to the authority's explanation, period required for fund application to operation commencement is approximately 4 months on an average. From the interviews with farmers, however, it is thought that much longer period is required. The mission considers it necessary to estimate the period at approximately 12 months. During this period, advanced funds are frozen.

Assuming that amount of water pumped is approximately 0.007-0.015 l/sec, irrigation acreage is 10-20 acres in case of Kharif crops, 10-12 acres in case of Rabi crops and 2-5 acres in case of summer crops.

There is an unpublished regulation that a new tube well should be drilled at a place 1,000 feet (1,500 feet if its diameter is larger than 6") apart from the existing tube wells and canals including village channels. Drilling of a state tube well is not allowed unless this condition is satisfied wells and the pertinent construction permission is granted.

Chapter V Agricultural Water Utilization in Respective Sub-centres

Six Sub-centres are located 4 to 74 miles from Arrah in the area extending along the main road connecting Arrah and Sasaram via Patna. As stated already, shahabad district is divided into three areas by the pattern of agricultural water utilization, namely, "Hilly Area", "Canal Area" and "Flooded Area". Of the six Sub-Centres, five are in the canal area, and the remaining one is located near to boundary of the canal area and flooded area. The common problem of all the six Sub-centres is that water supply can be hardly expected from the canal system despite the fact that they are located in the canal area or near its boundary. This suggests that irrigation involves many various difficult problems even in the canal area. Some tube wells were already drilled in the areas of respective sub-centres. It is understood that farmers are hoping for stable water supply from tube wells. Especially, the mission felt the farmers' strong desire for private tube wells which can be managed by farmers themselves.

Present condition of agricultural water utilization in respective Sub-centres is as briefed below (See Fig 4-3).

5.1 Saura (Dehri Block)

This Sub-centre is located in the area extending on the southern side of the Gaya-Benales road and along the left bank side of the Sone River, and is 74 miles from Arrah. Canals are distributed on the northern side of the above said road and far from the Sub-centre. Further, the Sub-centre has a larger elevation than the canal bed. Therefore, unless water is pumped up from the canals of a few kilometers in length are constructed, irrigation is not feasible. Amount of water drawn from the Sone is not enough for irrigation of the whole commanding area. For these reasons, irrigation by canal system cannot be expected. Presently one state tube well and 27 private tube wells are available, and these are said to supply irrigation water to 95 per cent of the whole area for Kharif crops, 80 per for of Rabi crops and 60 per cent for summer crops.

For connection of fields with the state tube wells, brick-made canals called Bakka channel are constructed. Water is conveyed directly to fields or earth canals through respective turnouts. Private tube wells observed by the mission are also provided with brick-made canals. Private tube wells belong to individual farmers. Since individual farm fields are not closed in a group, water must be conveyed to respective farm fields. Further, earth canal or Bakka channel will be required for effective utilization of pumped water.

This area is situated in the middle apex of the alluvial fan of the Sone River and Ganga River. Therefore, fluctuation of shallow groundwater level is considered to be fairly large. In taking groundwater from shallow wells, it must be borne in mind that the amount of water intaken fluctuates largely through the year. It is said that some of the private tube well owners sell surplus water at Rs. 12 per day. 1. Total length of Bakka channel is not clearly known. As for earth canal it is considered that there is much for improvement. In this area, pumped water is not pumped up again, nor is Ahar found.

Judged from maps of 1 inch to 1 mile in scale, this area is adjacent to the areas where many Ahars are distributed. Considering the natural and social conditions of the area, however, possibility for newly establishing Ahar is small. Local farmers rather expect that 5-6 tube wells will be drilled and cover the whole area with tube well network. 1: Rs. 1.5/hour; daily operation: 8 hours Conditions permitting, each tube wells shold be installed at a higher place within its commanding area so as to assure water supply to all fields and save the loss of double pumping.

5.2 Bikramganj (Bikramganj Block)

In reply to the Block Office's request, this Sub-centre is planned to be moved to another place within this year so that it was not taken as one of the subject areas. The Sub-centre is in the canal area, and is 4.5 miles in the direction of Sasaram from Arrah. According to the survey, irrigation ratio is 70 per cent in case of Kharif crops, and 50 per cent for Rabi crops.

Though the proposed new Sub centre area is included in the canal area, drilling of a few tube wells is planned to assure stable supply of water and thereby make it possible to carry out extension activities in a satisfactory manner. The new area is in the upstream area of the Sone River, and is blessed with good water use condition. Therefore, improvement and consolidation of the existing canal system should naturally be carried out.

5.3 Katar (Piro Block)

This area is located 30 miles from Arrah, and belongs to the canal area. Further, irrigation in this area is said to be completely dependent on the canal system at present. Water taken at Sone Barrage flows to Arrah Canal through main canals, and is conveyed to distributaries and village channels. The village channels run into the area after passing through a number of villages where they cross the arterial road connecting Arrah and Sarasom. The Sub-centre is located in the middlestream area of the Sone River basin. In other words, this area is located around the tail end of the irrigation system which is composed of main canals, lateral canals, distributaries, etc. Therefore, amount of water is scarce and the head is small.

The mission was informed that there used to be another channel entering this area. Use of this old channel was discontinued due to the lack of water, and it can no longer be found in the area. There are various reasons why the amount of water decreased in this area, i.e., increased of intake of water at Sone Barrage, sedimentation in main and branch canals, superannuation of irrigation facilities, poor operation and maintenance of facilities, increased intake of water necessitated by the expansion of cultivated area in villages located upsteam of this area.

As mentioned already, existing canals run through lower parts of the area and therefore, water cannot be conveyed to field ditches connected to village channels unless head is substantially increased by augmented water disc harge. However, since head increases only when water is not drawn in upstream areas during rainfalls, water supply in this area is in an extremely unstable state.

The area embraces some paddy fields whose elevation is so high that water cannot be distributed even when the water level of rivers and canals is very high. Water supply to such paddy fields calls for pumping operation by some means or other. All these paddy fields can be readily irrigated if water is drawn from other village channels, but this involves problems like traditional water right, purchase of land for channel bed, canal construction cost, etc. As a consequence, the area is obliged to resort to tube wells for water supply.

At present, the sub-centre area has only two private tube wells and the irrigation ratio stands at 85 per cent for Kharif crops, 40 per cent for Rabi crops and 5 per cent for summer crops. Though there are 6" diameter tube wells besides the two private tube wells, they are not used for agricultural purposes because they are owned by the Public Service Department. The existing private tube wells have a small diameter (3") and their command area is no larger than 10 acres for Kharif crops, 8 to 10 acres for Rabi crops and 5 acres for summer crops. The area has no perfectly paved canal system, but earth canals constructed along borders of paddy fields and waterways excavated in paddy fields by making use of borders may be said to be fairly well arranged if the question of quality is set aside. These earth canals and waterways are a good evidence to show the acute demand for water and high water-consciousness of farmers in the area.

Insofar as was discovered by the survey, practically all paddy fields are connected to waterways. It is therefore probable that when suitable number of tube wells are drilled at suitable places in future, they will be connected to the existing canals and make effective irrigation a reality. Ahar is found outside this area, but its utilization in this area is not conceivable either for the present or for the future. No drainage canals are found as in other areas, and it appears that farmers' attention is focussed on the supply of irrigation water.

5.4 Garhani (Charpokhari Block)

This sub-centre is situated midway between Arrah and piro about 20 miles from Arrah and is in the lower part of the Sone river basin. Though it is in Canal Zone, the sub-centre area is devoid of any village channel from the Sone and resorts solely to rain water and tube wells for irrigation.

A small river flows along one side of the area but its discharge is not stabilized. A 10 HP pump is installed at a site providing a 25 feet head, but this pump is not in operation due to electrical failure and other reasons. A weir is constructed on the downstream side of the pump site upstream of the light railway track, providing a washing place for the villagers. The pump is connected to a waterway. It is considered that a substantially wide area can be irrigated by drawing water from this waterway, but this will call for construction of a weir immediately downstream of the pump site to create a reservoir. Without such a reservoir, the pump operation will become impossible in no time. From the information obtained through interviews with farmers, the river does not seem to serve as stable water source, though this cannot be said for certain due to the absence of past hydrological data. Further, even if the said pump and waterway are put in effective use, it will be topographically impossible to cover the area extending on the opposite side of the road running through the area. There are three private tube wells at present. The mission examined one of them and discovered that its diameter is as small as 3". The mission was also infomred that the pumping operation causes large fluctuation of groundwater level. The area is situated at the edge of the alluvian fan and is therefore considred to abound in groundwater sources.

While the said private tube wells are shallow wells, both shallow-and deep-seated groundwater is utilized in the area. Besides these private tube wells, there is one 12" state tube well constructed by the Public Health Engineering Department. This well, however, is not in service condition at present because its wires are cut by rats. The discharge side pipe of this pump, which was laid by the said department, is connected to earth canals leading to neighbouring fields. Earth canals are also connected to private tube wells, but their length is rather small.

Elevation in this area varies considerably by place. Therefore, if the area is divided into a number of blocks and ground water irrigation is planned with the tube well sites selected in high places, not only the earth volume for canal construction will be reduced but also gravity irrigation will become possible. The irrigation ratio stands at 85 per cent for Kharif crops, 40 per cent for Rabi crops and 10 per cent for summer crops at present. If the above-mentioned state tube well is put in effective use, irrigation of about 200 acres will be possible.

Farmers in the area are reportedly coordinative with each other and eager about improving farm management. The mission therefore considers that extension service will prove quite fruitful if aided by the additional installation of private tube wells and effective utilization of the state tube well.

5.5 Ekauna (Udwanagar Block)

This sub-centre is located at a point 4 miles from Arrah in the direction of Sasara, and is closer to Arraha Agricultural Centre than all the other sub-centres. Since it is in the lower basin of the Sone, the sub-centre area is estimated to abound in groundwater. At present, however, groundwater utilization can be hardly observed.

The sub-centre has been operated at the present site since the 1969 Kharif season. Starting from the 1972 Kharif season, however, the sub-centre will carry out its activities at another place in the area to meet the strong request of the block office. Irrigation ratio is 85 per cent for Kharif crops, 40 per cent for Rabi crops and 5 per cent for summer crops.

The area is pressed hard for increased water supply in recent years consequent upon farmers' growning enthusiasm towards agricultural development. However, due to the inadequate water distribution practice, the area is placed under disadvantageous condition relative to the villages in upstream areas.

The survey disclosed that the canals connected to village channels are superanuated. What must be done at present to cope with the increasing demand for water would be to study, for one thing, how wide an area can be commanded by the existing irrigation facilities when they have been fully improved and to secure, for another, new water sources to cover the increment of demand.

New establishment of Ahar near the sub-centre area entails extreme difficulties by reason of converted land, construction cost, etc. Development of the rich groundwater sources would therefore be the only solution of the prevailing water shortage. Tube well drilling currently planned by sub-centre will contribute largely to the area's development. Topography of the area is rather flat, but is not considered to make irrigation so difficult.

Drainage canals are not found at present. Drainage appears to be one of the problems to be tackled in future.

5.6 Kulharia (Koilwar Block)

This sub-centre is located at a point 10 miles from Arrah in the direction of Pata, and is close to the boundary of Canal Area and Flooded Area. Since the sub-centre area extends over the merged land of alluvial fan, it is rich in groundwater sources and part of the area sustains damage when flood occurs.

A problem common to all sub-centres is that the density of distributaries and sub-distriburies is so low that the distance to canals is quite long. In Koilwar block, too, no canals can be seen within the range of vision. Groundwater and flood water are the main sources of irrigation water in the area. It leaves doubt, however, if flood water can be considered as water source because artificial flood control is not an easy task. The area's main water source is therefore groundwater.

The area has one state tube well and three private tube wells at present. Irrigation ratio is 85 per cent for Kharif crops, 60 per cent for Rabi crops and 10 per cent for summer crops. Farmers in the area show great eagerness for increasing the production of summer crops. Topography of the area is generally flat, and considerable moulding is observed in the canals connected with tube wells.

As seen in the map, there are many tube wells installed in the neighbourhood of the area, indicating that weight is attached to tube well irrigation including utilization of groundwater recharged by irrigation. This is because the area is in the lowermost part of the Sone basin and cannot therefore be covered by surface irrigation.

The mission noted that the pump house of the existing state tube well is inclined to one side by the last year's flood. The mission also learned that the existing state tube well was constructed 2 to 3 years ago because the old one became inoperative after 4 - 5 years' operation. A brick-made mortar finished Bakka channel connected to the state tube well branches into a number of routes, and then connected to earth canals leading to the fields. In the middle part of the Bakka channel, some turnouts are installed to introduce water into earth canals or directly into rields for plot-to-plot irrigation. The Bakka channel is about 48 cm in width and 30 cm in depth near the outlet of the tube well. The private tube wells, on the other hand, have a bore diameter of 3 - 4" and command an area of 20 acres for Kharif crops, 11 - 12 acres for Rabi crops and 4 - 5 acres for summer crops.

The mission was informed that in case water is supplied against payment, 40 paisa per KWH is collected and this includes the maintenance and other costs. Private tube wells are managed by farmers themselves and consequently seem to be put in effective use over a fairly long period relative to the tube wells operated by various agencies.

Private tube wells are annexted to earth canals and their section is not necessarily narrowed towards the tail end. It was noted that considerably many fields are linked with each other by such private tube wells.

From the reconnaissance survey of the canals annexed to these three private tube wells, the mission discovered that their tail ends are connected with eash other, constituting a sort of irrigation network (See Figs. 8-3, 8-5 and 8-9). This attracted the mission's attention though the actual irrigation method could not be investigated.

In the absence of no other water sources but groundwater, additional installation of tube wells is a must in this area. It is also felt that construction of drainage canals will become imperative in the coming years.

Chapter VI Recommendations on Irrigation Improvement

6.1 Introduction

Fig. 4-3 shows the map of Shahabad district.

In this chapter, recommendations on irrigation and flood control in Flooded Area as well as irrigation in Canal Area are presented in compliance with the request of Mr. Sharma, a vice-minister of Agriculture of Bihar state.

Generally speaking, regional development in these two areas is impeded by the delayed consolidation of tertiary facilities and poor organizing capability on the part of farmers who are to undertake the management of such facilities.

6.2 Flooded Area

6.2.1 Improvement Target

Improvement target should be studied under two categories, i.e., long-term target and short-term target which need to be quickly attained.

1) The following items are to be included in the long-term target.

a) Establishment of a well consolidated irrigation and drainage system.

It is desirable that the whole area be covered by an irrigation system in which tube wells are suitably combined with the canal system as described later. Establishment of such a system should be accompanied by the creation of a network of drainage canals.

Natural drainage is expected to be made occasionally impossible by the rise of water level of the Ganga in the flood season particularly after flood control becomes possible by the completion of river banks and other facilities. In planning the construction of drainage canals, therefors, including this problem should be given due consideration in order to establish a drainage system which is perfectly balanced with the irrigation system.

b) Modern field consolidation.

Establishment of an irrigation and drainage system should be promoted concurrently with a systematic field consolidation work in the whole area involving plot rearrangment, land exchange and consolidation, and farm road arrangement. If construction of main canal facilities goes ahead leaving the improvement of tertiary facilities behind, there will arise problems similar to those now encountered in Canal Area. Creation of a modern irrigation and drainage system should always be accompanied by modern field consolidation work.

c) Consolidation of agricultural production facilities and introduction of mechanized farming.

After field consolidation should come the consolidation of a system for agricultural production facilities such as rice mills and repair centres as well as full-scale introduction of farm machinery and equipment. The importance of such measures within the framework of the long-term agricultural improvement plan should be made clear together with the time of initiating them.

d) Integrated development of rural communities.

Items a) to c) above relate to the increase of agricultural production, alone. Hence, a master plan for integrated regional development incorporating improvement of living environments and industrial development should be worked out from the long-term viewpoint. Various agricultural improvement plans should be included and given clear position in this master plan. Note must be taken of the danger involved in attaching too much importance to agricultural production, particularly production increase.

2) It is desirable that the following items be included in the shortterm target.

a) Alleviation of flood damage.

As will be described later, construction of flood banks along the Ganga and the Sone is the most economical and radical measure for realizing flood control, but this calls f for a considerably long construction period. Hence, in areas where productive agriculture is carried out by virtue of irrigation facilities like tube wells and farmers' financial capability is high, it is desirable that measures be taken for partial flood control even if such measures incur a high cost per unit area, provided, however, that the recovery of the construction cost is guaranteed.

Further, efforts should be made for minimizing flood damage inflicted on respective villages. At present, farmers are obliged to evacuate their village to take refugee from a flood. Remedy should be brought to this situation as soon as possible.

b) Maximum utilization of existing irrigation facilities.

As described later, existing irrigation facilities which comprise chiefly tube wells are not utilized to the fullest extent. It is to be noted that promotion of productive agriculture through effective utilization of existing facilities is very meaningful in that it gives incentive to the introduction of irrigation facilities in non-irrigated areas.

c) Additional installation of tube wells.

In Flooded Area, irrigation facilities are distributed only in the southern part where the elevation is relatively high. It is desirable that the present distribution of irrigation facilities be expanded to cover the northern part of the area while taking suchflood control measures as closing dyke construction.

d) Commencement of surveys for basic data collection.

As described later, observation should be carried out uninterruptedly over a considerably long time in order to obtain accurate data on the availability of groundwater and discharge of surface water from Canal Area. It is desirable that such long-term observation activity will be commenced at an early data.

6.2.2 Evaluation of Existing Condition

6.2.2.1 Existing Condition of Flood Control

The mission received the impression that agriculture in Flooded Area is such that "attempt at improvement which is fully realizable is abondoned simply because of the anticipated flood." It seems quite possible to extend systematic irrigation farming from south to north even before perfect flood control is realized only if such an attempt is backed up by the enforcement of active improvement plans. The mission felt that the people's reluctance in fighting flood is ascribable to the fact that flood in this area is not so destructive and brings about sizable benefit besides causing damage.

6.2.2.2 Utilization Ratio of Existing Irrigation Facilities

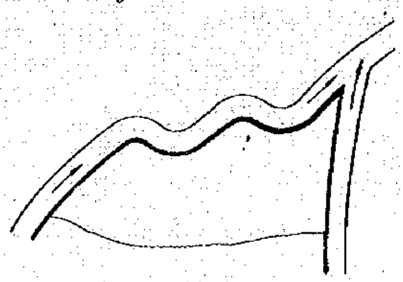
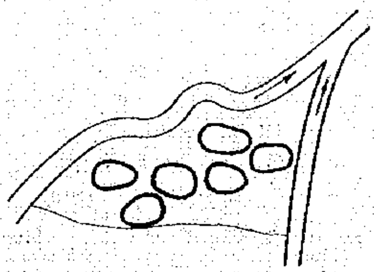
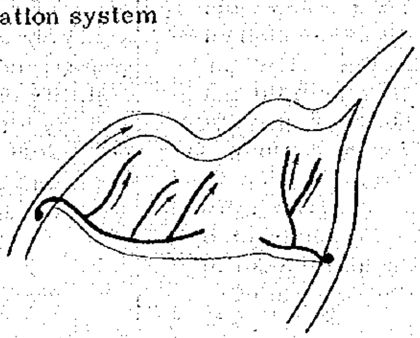
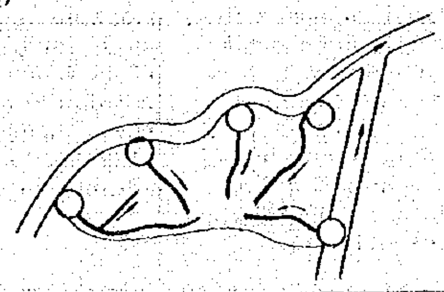
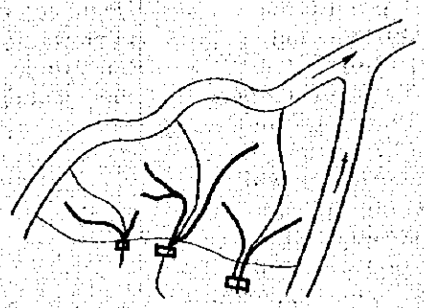
In general, irrigation facilities do not seem to be utilized to capacity. They are left idle for many hours and days. In particular, the present operating hours of tube wells is far from sufficient. Since facilities like tube wells can be put in automatic operation for substantially long time once set at a fixed service condition, extension of their operating hours should not be too difficult. The benefit of perfect irrigation is not only very large but can also be readily enjoyed in this area by small investment and some contrivance. Lack of will to "try an improvement ifeconomically feasible" is observed in both table No. 2) and 4). It is to be regretted that many valuable facilities including those for pump irrigation are left idle for many hours.

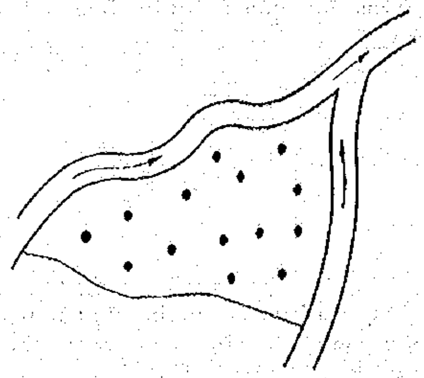
6.2.2.3 Installation of Additional Irrigation Facilities

As mentioned in table No. 3), the benefit of irrigation is very large in this area and can be obtained by very small investment. Tube wells, in particular, provide a water source which can be obtained with ease and at a low cost. From the existing distribution of tube wells, however, it can hardly be said that advantage is fully taken of the area's favourable condition.

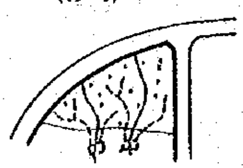
6.2.3 Concrete Plans for Improvement of Flood Control and Irrigation

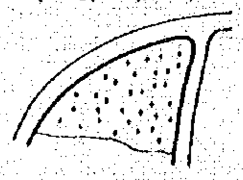
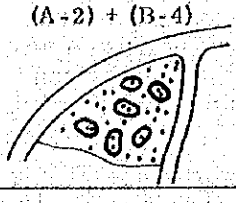
Improvement plans are proposed below by combining the data shown in the following table.

Sketch Map	Explanation
A, Flood control system (A - 1) 	Complete river dikes should be constructed along the Ganga and the Sone.
(A - 2) 	Construction of closing dikes should be commenced in the area where the requested for flood control is made by farmers, and should be continued as long as possible.
B. Irrigation system (B - 1) 	Canal system should be established by drawing water from the Ganga or the Sone.
(B - 2) 	Water should be pumped from the Ganga and the Sone.
(B - 3) 	Water should be conveyed from small and medium rivers which originate in Canal area.

Sketch Map	Explanation
(B - 4) 	Tube wells should be widely established in the whole area.

The following alternative plans were prepared by combining the data shown in the preceding table for comparative study.

No.	Sketch Map	Characteristics and Problems	Evaludation
1)	(A-1) + (B-1) + (B-4)	Discharge of the Sone drops to almost zero in the drought season and therefore year-round intake of a large amount of water will not be possible. Further, since the Ganga has a very mild bed slope, water conveyance by gravity method is not considered feasible. In addition, the Ganga's unstable course would make the intake of water difficult unless an intake weir is constructed, but construction of such an intake is not justified due to the absence of a wide benefited area.	It is advisable to examine the relationship between the discharge and river bed stability of the Ganga and the elevation of cultivated area. Plan 3) is considered more advantageous.
2)	(A-1) + (B-2) + (B-4)	Installation of large capacity pumps for drawing water from the Sone will not be practicable due to the shortage of discharge. As for the Ganga, it is advisable to provide not many small sized pumps at places closer to upstream side. It is to be noted, however, that the operation cost of these pumps is liable to become high due to unstable river cource and power supply.	It is advisable to examine the discharge and river bed stability of the Ganga and the possibility of stable power supply. Plan 3) is considered more advantageous.
3)	(A-1) + (B-3) + (B-4) 	If small rivers flowing out from Canal Area have stabilized and copious dischage, then this plan is better for securing the sources of surface water than Plans B-2 and B-3. It is advisable to utilize such water sources to the utmost, while systematically covering the water shortage with the groundwater source recharged by irrigation water in Canal Area. It is necessary, however, to make a survey on the maximum availability of both surface	Deserves studies and reviews as one of long-term improvement plans.

		water and groundwater. This plan is advantageous in that headwork will not be influenced by flood.	
4)	(A-1) + (B-4) 	If the abovementioned discharge is not sufficient for irrigation of a fairly wide area, then it may as well be suggested to resort to groundwater alone. In this case, amount of groundwater available is an important factor.	
5)	(A-2) + (B-1) + (B-4)	Construction of such a full-scale irrigation system before completion of the flood control works is not justifiable particularly because it will make Kharif crops unstable.	Not advisable as a long-term improvement plan.
6)	(A-2) + (B-2) + (B-4)	- do -	
7)	(A-2) + (B-3) + (B-4)	- do -	
8)	(A-2) + (B-4) 	Deserves consideration as a provisional measure, but not satisfactory as a long-term plan. Additional installation of tube wells should be carried out for future application of Plan 3.	Deserves to be promoted as a tentative measure.

The alternative plans studied above can be summarized as follows.

A. Long term improvement should be prompted on thebasis of Plans 3) and 4) with detailed studies made on the following items.

a) Extensive study on the availability of groundwater.
b) Discharge measurement of smaller rivers.
c) Surface grade in Flooded Area.
d) Stability of longitudinal and cross sections of the Ganga's river channel.
e) Annual discharge of the Ganga.

It is possible that the outcome of these detailed studies will necessitate further reviewal of Plans 1) and 2).

B. For improvement in the immediate future, it is considered advisable to implement Plan 7) in areas where the flood damage is relatively small and farmers exhibit high volition for improvement and organized activities. The plan should be implemented in the following order.

Creation of irrigation association → installation of tube wells → construction of closing dykes.

In the course of the plan's execution, due attention should be paid to the balance between the irrigation by small rivers envisaged by Plan 3) and that by tube wells, maximum availablity of groundwater, as well as the discharge of smaller rivers and findings of the extensive groundwater survey.

For permanent and perfect flood control, river dikes should be constructed along the Ganga and the Sone, but this plan calls for a prudent study of the smaller rivers flowing down from Canal Area. If a sluice is constructed at the estuary of these rivers, the length of dike can be made smaller but the low-lying parts of the area will be submerged when the Ganga's water level is high unless flood water of these rivers is drained by pumps. If, again, these smaller rivers are connected to the Ganga and dykes are extended towards their upstream, the length of dike will be made so much the larger. Even in this case, drain water will retain in the area when the Ganga's water level is high. Fig. 4-6 shows the length of dike envisaged by these two plans (length per unit area and total extension). Since the dike need not have a large height, the latter plan appears a little more advantageous but detailed comparison of the two plans should await the completion of the survey now being conducted by the state government.

Construction of a network of small type closing dikes usually requires a long dike length per unit area and is neither economical nor suited for systematic creation of a drainage network. Hence, it is not recommended as the long-term improvement target.

6.2.4 Studies and Recommendations on Closing Dike

A closing dike is constructed to meet various purposes such as 1) flood control for the farmland area within the dike, 2) storage of water for irrigation of farmland area outside the dike, and 3) flood control in agricultural clusters. It also serves to introduce the desired amount of flood water in the flood season for supply of silty soil. When the outside flood water level is high and natural drainage is not feasible, rain water retains within the dike, but installation of drainage pumps is not usually required unless the difference between the outside and inside elevations is excessively large.

If a closing dike is used for stroage of irrigation water to be supplied to other areas, cropping within the dike during the storage period is given up. Kharif crops cannot be totally given up since they are main crops. For cultivation of summer crops, however, it may as well be suggested to use a closing dike as reservoir if water can be readily drawn from adjacent rivers or tube wells.

Closing dikes used as reservoir are not considered very efficient because of the small water depth and large permeation and evaporation loss. Cultivation of summer and Rabi crops resorting to the high water utilization techiques described later is therefore recommended if a suitable water source is available in the neighbourhood.

Construction of closing dikes for flood protection of agricultural clusters should be given closer attention as part of public works. At present, farmers are obliged to evacuate their home each time flood attacks their village and this practice retains their living environments on a low level. In the absence of accurate and long-term statistical data, nothing definite is known about the flood damage suffered by farmers. The damage, however, is believed to amount to a considerably large amount in some areas. Construction of closing dikes for flood control does not incur a very large cost as described later, and is therefore recommended to be prompted, together with the construction of dikes for farmland irrigation, in areas where the inhabitants express concerted desire for their installation and if the river dike costruction along the Ganga and the Sone is delayed.

6.2.5 Intensive Utilization of Tube Wells

If tube wells are to be installed, it is desirable that they be utilized to capacity. For this purpose, the following improvements should be effected.

A) Intake of water to the full capacity of pumps and tube wells.
   A)-1 Extension of daily operation hours.
   A)-2 Careful inspection and protection of strainers and pump impellers.

B) Effective utilization of pumped water.
   B)-1 Minimization of conveyance loss (e.g., installation of temporary pipe lines for water distribution and other means).
   B)-2 Creation of a farmers' irrigation association for expansion of benefited area and maximum utilization of water.

To materialize these improvements, particularly Items A)-1 and B)-1, the following measures are proposed.

First of all, the command area should be enlarged by increasing the daily operation hours, and this in turn will call for an emergency power source with which to provide against service interruption and voltage drop of commercial power. A diesel engine has a life span of about 5,000 hours and can therefore be used for 2 to 3 years if put in year-round operation at a rate of 10 hours a day. Needless to say, diesel engines can be employed as the only power souce until commercial power supply becomes stabilized.

In the second place, it is desirable to provide a reservoir for temporary storage of water pumped up at night and to install temporary water pipes for distribution of irrigation water in the expanded command area. It is also desirable to establish a complete distribution system by construction new small earth canals. If converted land and construction period become limiting factors in the establishment of such a system, it may as well be recommended to construct temporary waterways either on the ground surface or underground, whichever may be expedient.

A 4"ϕ centrifugal pump has a capacity of about 0.65 - 1.25 m^3/m. For safety's sake, 0.9 m^3/min = 0.015 m^3/sec is adopted in calculation, and the daily operation hours is assumed at 20 hours.

Assuming that the amount of water supply is 6.5 m/day x 1.15 = 7.5 mm/day from Tables 4-10 and 4-17, the command area for cultivation of Kharif crops can be calculated as follows.

0.9 m^3/min x 60 min x 20 hours/day ÷ 75 m^3/ha = 1,080 ÷ 75 = 14.4 ha = 36.6 acres

The command area of Rabi crops can be calculated as follows assuming that the amount of water supply is 2.5 mm x 1.20 = 3.0 mm/day from the standard value shown in Table 4-11.

1,080 m^3/day ÷ 3.0 m^3/ha = 36.0 ha = 90.0 acres

If the cropping ratio os 60%, the gross command area will be 60 ha (150 acres).

The command area of summer crops can be likewise be calculated as follows by assuming that the water supply is 10 mm/day x 1.15 = 11.5 mm/day from Tables 4-10 and 4-11.

1,080 m^3/day ÷ 115 m^3/ha = 9.4 ha = 23.5 acres

If a tube well is at the centre of this command area, water conveyance can be carried out as described below.

Kharif crops: No temporary reservoir should in principle be provided because the whole area will be cultivated, and water will be conveyed directly from the tube well through small canals or pipes to the maximum possible extent. Amount of nighttime water supply is 540 m^3/10 hours, which can cover 0.6 ha land because per ha water supply amounts each time to 7.5 mm/day x 12 days = 90 mm = 900 m^3/ha and irrigation interval is 12 days. If small canals are arranged and set in advance for impartial water distribution, changeover of canals at night will not be necessary. If the command area is far from the tube well, it is advisable to employ the method shown in Fig. 4-8. In other words, irrigation should preferably be conducted consecutively in the order of Block A→Block E with a time lag of ____ days provided in the rotation programme.

Rabi crops: Unplanted paddy fields are to be water-sealed and provided with high borders so as to be able to store water to a depth of 30 - 40 cm. Water pumped up during 10 hours at night is to be stored in such paddy fields. If 540 m^3 of water pumped up at night is to be stored to a depth of 30 cm, an area of 0.18 ha will be required. Since both storage loss and conveyance loss are inevitable, it is better to distribute water through the night by fixing small canals. Amount of each water supply is 3.0 x 2.5 = 75 mm = 750 m^3/ha in case the irrigation interval is 25 days. Accordingly, 540 m^3 of water suffices for irrigation of 0.72 ha. Since the area is not very wide, changeover of small canals at night will not be strongly required. If water is stored in the temporary reservoir at night, it can be distributed during the daytime of the following day. For prevention of permeation loss, use of polyethene sheets is commendable. A polyethylene sheet measuring 45 m x 45 m is large enough to cover the abovementioned reservoir.

Assuming that the cropping ratio is 60 per cent, the total acreage of command area turns out to be 60 ha, which is equivalent to 150 acres. The five block water distribution system is applicable in this area as illustrated in Fig. 4-6. In this system, rotation can be planned at a rate of 5 days per block.

Summer crops: Installation of temporary reservoir and pipelines can be planned in much the same manner according to the distribution of paddy fields because the only difference is that the command area becomes smaller than in the case of Kharif crops.

In order to study the economic advantage of this system, trial calculation was worked out on the assumption that perfect irrigation farming will bring about a profit increase of Rs 440/acre (Rs 1,100/ha) for Kharif crops, Rs 200/acre (Rs 500/ha) for Rabi crops and Rs 960/acre (Rs 2,400/ha) for summer crops. The calculation disclosed that the system would yield the following increase in the yearly return from respective crops.

Kharif crops	Rs 1,100/ha x 144 ha = Rs 15,800
Rabi crops	Rs 500/ha x 36.0 ha = Rs 18,000

Summer crops	Rs 2,400/ha x 9.4 ha = Rs 23,000
Total	Rs 56,800

Organizations for agricultural water utilization should be established for smooth management of the irrigation system. The mission considers it most appropriate to embark in the creation of such organizations in key places like sub-centre areas. If these organizations are expanded in scale in future to cover a whole area, extension work will be undoubtedly facilitated to a large extent.

In order to meet the water demand during about 50 days from the end of the monsoon rainfall season up to the end of the irrigation period, it is advisable to store wet season water up to the limit phisiologically allowable for the growth of paddy. During the said 50 day period, paddy grows to a height of 110 to 120 cm and the storage limit of water is considered to be about 250 mm. Assuming that the daily water requirement in depth is approximately 9 mm, this 250 mm of water is equivalent to the irrigation water requirement for 28 days. In areas provided with well developed irrigation facilities, such storage of water is not an absolute need. Nevertheless, it is advisable in that it serves to cut down the pump operation cost.

6.3 Canal Area

6.3.1 Improvement Target

1) The following items are to be included in the long-term target.

   a) Improvement of the existing Sone Canal system into a modern irrigation system complete with satisfactory tertiary canals.
   b) Enlargement of benefited area of systematized irrigation through improvement of the Sone Canal system.
   c) Modern field consolidation including land adjustment, exchange and consolidation, farm road arrangement, and consolidation of irrigation and drainage canals.
   d) Consolidation of agricultural productive facilities and acceleration of agricultural mechanization.
   e) Inegrated development of rural communities involving environmental improvement and industrial development in the whole area.

2) It is desriable that the following items be included in the shortterm target.

   a) Inspection of water lacking parts in the command area, and provision of a supplementary water source, if necessary.
   b) Increase of village channels, and establishment and extension of a fair and rational water management system by farmers' own efforts.
   c) Execution of surveys for collection of basic data necessary for mapping out a long-term improvement plan and general review of the existing Canal system (e.g., area-wise survey of groundwater, measurement of water requirement in depth and conveyance loss in canals, and discharge measurement at respective points in canals).

As for the long-term target, it is recommended that the Bihar state government make endeavours for its materialization from a macromatic viewpoing while maintaining balance wi with the development in other parts of the state. General improvement plan is introduced in Paragraph 6.3.3. and a detailed explanation of the short-term improvement plan is given in Paragraphs 6.3.4 and 6.3.5.

6.3.2 Evaluation of Existing Condition

Irrigation improvement cannot be brought to an end merely by the completion of headworks and main canals. Unless integrated consolidation of the entire facilities including terminal ones is completed and most effective use of irrigation water is guaranteed, irrigation facilities do not demonstrate their intrinsic value. One of the pressing needs in this area is to bring solution for the problems in terminal areas.

However, many of such problems cannot be readily solved because they call for the improvement of farmers' termers' technical level as well as their organized activities.

Item-wise Evaluation of Existing Condition

No.	Item	Evaluation
1	Main water source	
1-1	Is the discharge of the Sone sufficient?	No. The discharge fails to meet the demand from the existing Sone Canal in certain years and seasons. The shortage will become acuter when Sone High Level Canal and Koel High Level Canal are completed, but this is planned to be coped with by the construction of Kutku dam. It is therefore hoped that Kutku dam will be completed at an early date and the Bansagur Dam Project in M. P. state will be coordinated with Kutdu dam construction.
1-2	Is the management and operation of Sone barrage satisfactory?	Yes. Sone barrange is a modern structure and both its management and operation are satisfactory.
2	Main canal (down to distributary)	
2-1	Is the management satisfactory?	No. Considerable silt sedimentation was observed in April 1972. Though it is understandable that there have been no chances for repairing the canal since 1966, it is to be pointed out that the planting of Rabi and summer crops will keep on increasing in the coming years. 6 years is too long a time to operate any large canal without a single repair service.
2-2	Are the water diversion and discharge measurement conducted accurately?	Discharge measurement cannot be considered satisfactory. Considering the scale of the canal, the measurement should be conducted in a more accurate manner. The poor discharge management method currently employed presents an awkward contrast to the modernized management of Sone barrage.
2-3	Are the rules for water conveyance easy to understand and rational?	Under the existing rules, water supply to distributaries is continued for 10 days and then suspended for 4 days. The mission does not condider that this system is the best. Detailed explanation will be given in Item (3).
2-4	Is the design canal discharge adequate relative to the irrigation water requirement?	The design value is assumed to be adequate though its calculation criteria were not made known to the mission. The mission wishes to know how drought year and maximum annual canal discharge were treated in planning the design value.
3	Terminal canals	
3-1	Are the canals distributed appropriately?	Considering the farmers' present management capacity, the length of village channels which are left to their care seems to be too long. Further, it is considered that the length of village channel per unit area should be extended.
3-2	Is the management satisfactory?	There is much room for further improvement. Conveyance loss seems to be very large.
4	Supplementary water	
4-1	Are tube wells effectively utilized?	No.
4-2	Is it necessary to develop new supplementary water sources?	Though nothing definite can be said without a detailed survey on the water distribution in the whole area, tube well development will be indispensable

for solving water shortage in areas not irrigable by canals. Utilization of smaller rivers should be given consideration besides tube well development. It is recommended to check how far irrigation water reaches in the existing command area.

6.3.3 Concrete Plans for Improvement of Sone Canal System

a) Sone barrage and river discharge.

It is hoped that the water source development plan centering on the Kutka dam construction will be materialized at an early date.

b) Overall survey of command area.

The boundary of Sone canal's command area should be plotted on the village map. Further, both place and acreage of those parts which are constantly in want of water should be made clear, with the cause of water shortage explicitly indicated (e.g., undulation is heavy, or plot-to-plot irrigation necessitated by lack of village channel is made impossible by water consumption in upstrea areas). For this purpose, it is desirable that contour lines be drawn on the village map at intervals of 3 to 4 ft.

c) Maintenance and reapir of main canal.

It is not considered essential to drain water from all the canals and give up cropping for a whole season. However, maintenance and repair service should be performed at least every two years.

d)° Rules for water conveyance.

It is recommendable to abolish the existing rule under which water supply to distributaries is continued for 10 days and then suspended for 4 days, and employ in its place a new and simple continuous daily irrigation system. Details of this new system will be explained later.

e) Accuracy improvement of water diversion work.

At each diversion point, accurate discharge measurement and checking of water conveyance capacity should be conducted with a water gauge and a staff guage graduated in percent installed. The diversion work should be made simple are improved in accuracy by 4) and 5). Further, a parshall flume also graudated in per cent should be installed at the gate of village channels.

f) Increased provision of village channels.

In areas where the deficiency of village channels is discovered by the survey mentioned in 2), provision of additional village channels should be prompted under the guidance of irrigation engineers. This will call for the enforcement of measures mentioned later in 7) and 8).

g) Development of supplementary water sources

In water lacking areas outside the benifited area as well as in those parts of the benfited area which are far from the village channel and had better seek a new water source rather than to construct a village channel through other villages, development of supplementary water sources should be accelerated by digging tube wells or drawing water from smaller rivers.

h) Establishment of farmers' irrigation association

A farmers' irrigation association should be organized for establishment and management of new village channels as well as for fair and rational management of terminal irrigation facilities.

i) Checking of design canal discharge

Since the present survey was conducted during the period when the canals were dry, the mission was not able to grasp the existing water distribution condition. It appears, however, that heavy conveyance loss is sustained especially in terminal canals. The design discharge shown in Table 4-2 is rather small though it was obtained by adding the conveyance loss in the existing canals to the standard water requirement in depth. It is probable that this is the reason why irrigation water does not reach every place in the command area.

j) Full utilization of existing water sources

As already mentioned in Paragaraph 2.5, Chapter V, it is desirable that all the existing water sources including tube wells be fully utilized and that the deep irrigation method be applied for effective utilization of wet season water.

6.3.4 Rules for Water Conveyance

Through interviews held during the present survey, it was revealed that water is conveyed each day to main and branch canals, whereas water supply to distributaries and village channels is conducted by a cycle of 14 days composed of 10 days of continuous sypply and 4 days of suspension. This water distribution system involves the following problems.

a) The section of distributaries and village channels need to be enlarged by a minimum of 14/10. Non-existence of such enlarged section leads directly to water shortage.

b) Canal operation is made quite complicated under the prevailing system. Assuming that there are a number of branch canals with 100 cusec of capacity and distributaries having a capacity of 15, 30, 20, 18, 27 and 30 cusec, the rotation should be so planned that the total discharge will be constantly maintained at 100 cusec and water will be supplied to each distributary by the aforementioned cycle of 14 days (10 days' supply followed by 4 days' suspension). This is in no way an easy task.

c) When the inflow into branch canals declines due to the discharge drop of the Sone, distributaries to which water is supplied at that time inevitably suffer disadvantage. Further, control of canal discharge according to rainfall and growth of crops is made difficult.

d) Conveyance loss tends to become smaller with the decrease in the number of canals, but this does not constitute a decisive advantage of the existing system because greater loss is incurred at the start and end of water conveyance operation due to the evaporation of water left in the canals.

e) Under the general irrigation method shown in Table 4-11, water is to be supplied at intervals of 20 to 25 days for Rabi wheat cultivation. Considering the present density of village channels and smaller canals, it is not likely that their operation will make it possible to convert the said general method to the rotation system. The only plausible way to apply the rotation system at present would be to divide the whole area into 21 blocks and supply water to 14 of them continuously for 10 days per each 14 days for plot-to-plot irrigation at intervals of 21 days. This method, however, is not only complicated but also demands that plot-to-plot irrigation be applied in the greater part of the area because blocks not covered by Setta are mixed with those covered by it.

The mission considers that the continuous watering method is more advantageous than the rotation method if solution is to be brought for these problems.

Under the continuous watering method, all water gates will be fixed to maintain design discharge in all canals and their free operation must be strictly prohibited. If discharge between certain two dates is set in advance at 80 per cent of the design value by means of the staff gauge mentioned in Paragraph 5.2.3.5, it should become possible to cope with the discharge drop of the Sone and even to control the canal discharge by cropping season and growth condition of crops. The mission is of the opinion that the application of the rotation system should be avoided except when the canal discharge drops to excess (e.g., below 50 per cent of design value). For paddy fields to which water does not reach, it is desirable to enforce a rule for supplying water continuously until water reaches their end so that the necessity for watering can be judged simply by checking each paddy field.

For reasons described above, the simple and continuous irrigation is considered suitable for this area. With regard to Kharif paddy, it is advisable that all paddy fields in the area be included benefited area on the premise that a new system will be established under which supply of necessary amount of water at the right time can be guaranteed. Establishment of such a system is made an imperative by the impractivability of supplying water for plot-to-plot irrigation only to those fields which are covered by Satta. However, final decision on this system should naturally be made with due account taken of the farmers' opinions and hopes.

6.3.5 Additional Provision of Village Channels and Their Management by Farmers' Irrigation Association

In the 17 lakh acre wide command area, canals larger than distributaries have a total length of 1,575 miles and an average density of 0.92 miles per 1,000 acres (3.37 km/km^2). Density of village channels is not known due to the absence of data. Management of terminal canals including village channels is left to farmers at present. Judging from the abovementioned density of main canals, i.e., 0.92 miles/1,000 acres (3.7 m/ha), it is considered essential to establish an irrigation association which would undertake the management of terminal canals.

Plot-to-plot irrigation does not fully exhibit its function in this area due to its mild slope and as a consequence, considerable amount of water is seized in upstream blocks. Water in village channels is also seized in upstream blocks because intake of water in downstream blocks is made difficult by the low channel bed elevation. It is impossible to bring remedy to such unfair practice by administrative power alone. If the state government is to exercise its power for direct control over water distribution, then the services of a large number of officials will be required and each of such officials will be demanded to have high moral sense.

One can readily point out that the most prominent drawback of Sone Canal System is the poor network of terminal canals smaller than village channels and want of organized activities of farmers by whom the network is managed. What must be done in future above all other things is to establish a systematic terminal canal network as part of public works implemented under the direct control of the state government and to entrust its management to an irrigation association organized by farmers themselves. If this is not practicable, model construction work should be undertaken by farmers with the technical guidance of the state government in order to set an example which can be extended and modelled after in other areas. Since no land readjustment has yet been initiated in this area, terminal canals constructed by farmers will be required to have a large density. Hence, it is desirable that the construction work be successively followed by other improvement works so as to attain the stage of land consolidation in a short time. If such rapid development is not feasible, a steady step forward should be made while allowing plot-to-plot irrigation to some extent.

If a small canal is to be arranged on both sides of blocks each measuring 20 x 30 m for plot-to-plot irrigation over five plots, then the density of canals will have to be about 100 m per 3 ha provided that the interval between canals is set at 300 m. In Japan, the standard block area with no plot-to-plot irrigation is 0.3 ha if the interval is 200 m and about 2 ha if the interval is 100 m.

Chapter VII Present Condition of Groundwater Development

7.1 Existing State of Groundwater Utilization

Groundwater utilization for agricultural purposes has a fairly long history in India. According to the statistical data collected during the survey (Ref. Bibiliography), the country's total well irrigation area registered 40.5 lakh ha in 1900/1901, which increased to the value shown in Table 7-1 in 1962/1963. As will be clear from this table, the area doubled during the last 60 years or so, occupying at present as much as 30 per cent of India's total irrigation area.

These facts clearly point to the importance and advantage of groundwater irrigation and to the continued groundwater development in future. Especially in areas extending along the Ganga are found huge alluvial and diluvial formations providing ample ground water sources. In these areas, copious ground water sources present a sharpl contrast to river water which is easily influenced by rainfall and cannot therefore become stable water source unless storage facilities like dams and reservoirssre constructed.

Irrigation area and its ratis by water source in Shahabad district are shown in Table 7-2. (Ref. Bibliography 2).

Table 7-1 IRRIGATION AREA AND ITS RATIO BY WATER SOURCE

Water Source	Irrigation Acreage	Ratio of Irrigation	Remarks
	(10^3ha)	(%)	
Government canal	9,690	37.7	
Private canal	1,170	4.6	
Tank	4,730	18.4	
Well	7,660	30.0	
Others	2,390	9.3	
Total	25,640	100.0	

Table 7-2 IRRIGATION AREA AND ITS RATIO BY WATER SOURCE IN SHAHABAD DISTRICT, BIHAR STATE

(Unit: 10^3 ha)

District		Arrah		Buxar		Sasarum		Bhabua		Shahabad [1]		Shahabad [2]		Rmarks
Cultivation area										792.8				
Irrigation area		112.9		85.4		202.2		74.5		475.0		435.3		Increase of 39.7
Water source	Canal	80.5	7.13	68.4	80.1	145.7	72.0	32.4	43.5	427.0	68.9	253.5	58.2	
	Tank	10.1	9.0	0.4	0.5	7.7	3.8	18.2	24.4	36.4	7.6	133.6	30.7	
	Tube well	9.3	8.2	8.9	10.4	24.7	12.3	11.3	15.2	54.2	11.4	0	0	
	Well	4.9	4.3	2.4	2.8	4.9	2.4	6.9	9.3	19.1	4.0	17.0	3.9	
	Others	8.1	7.2	5.3	6.2	19.2	9.5	5.7	7.6	38.3	8.1	31.2	7.2	
Ratio of irrigation area (%)										60%				

Remarks:

/1: Data in 1969/70

/2: Data in 1965/57 for reference

From Tables 7-1 and 7-2, characteristics of Shahabad district as compared with whole India can be summarized as follows.

(1) Ratio of the canal irrigation area to the total irrigation area is as large as approximately 70 per cent, equivalent to 3.27 lakh ha. This high ratio is attributable chiefly to the completion of Sone barrage on the Sone upstream and intake of water at this barrage for supply to Arrah canal.

(2) Ratios of irrigation areas resorting to other water sources are made small by the improved canal system. In particular, the ratio of areas depending on wells and tubes for irrigation is as small as 15 per cent.

(3) Comparison of figures for 1965/1957 and 1969/1970 reveals that in the latter period the canal irrigation area expanded by about 10 per cent, while the tank (plate-shaped storage pond) irrigation area decreased by 75 per cent.

(4) Well (shallow open well) irrigation area and its ratio have maintained the same level, whereas the tube well irrigation area introduced since 1955 increased rapidly by 11.4 per cent to 5.42 lakh ha. This is considered assignable mainly to the systematic groundwater exploration conducted by the Exploratory Tube Well Organization since 1955.

(5) Arrah division where Arrah Centre and its sub-centres are concentrated is favoured with water sources nearly equivalent in ratio to the average of Shahabad district. However, the canal irrigation area in the division is about 2.4 per cent wider than the district-wide total and the tube well irrigation area is 3.2 per cent smaller.

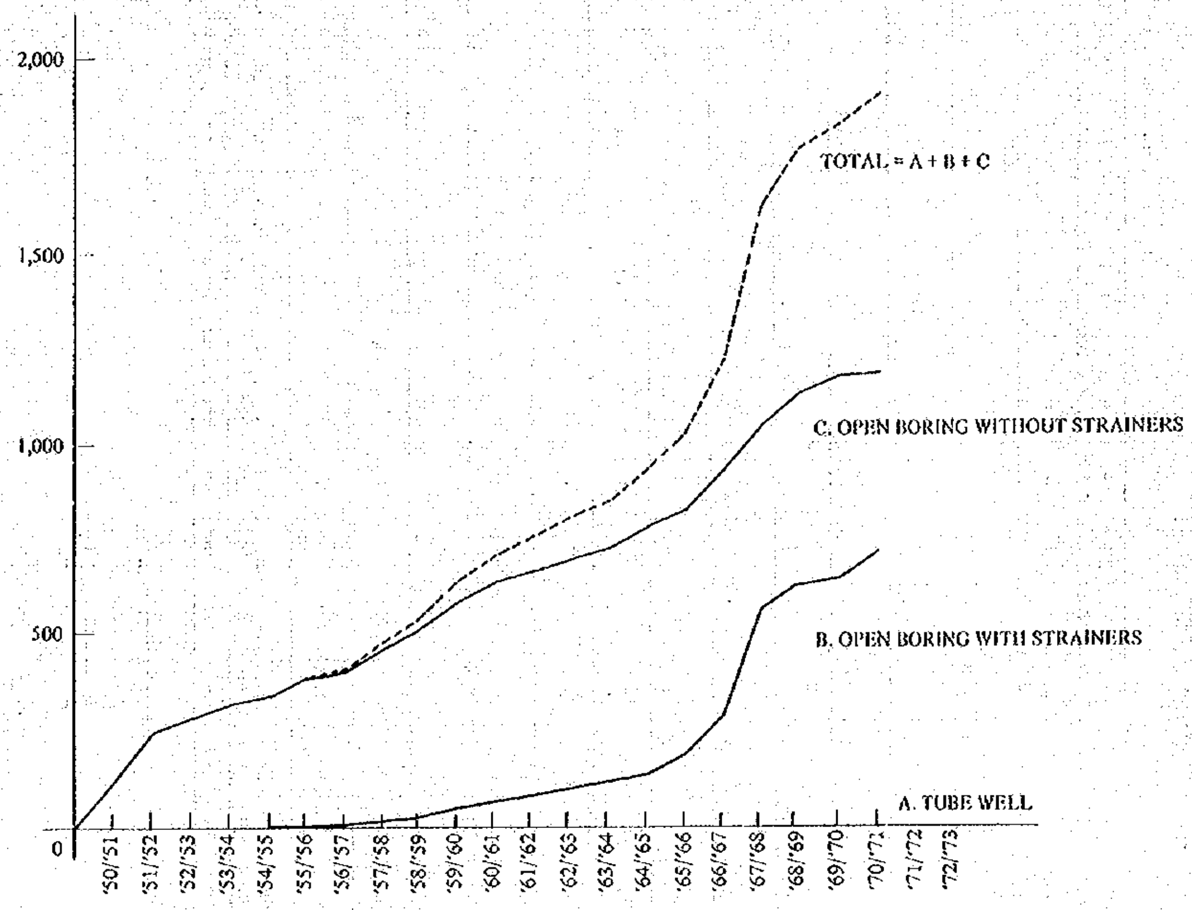
(6) Irrigation is planned for 60 per cent of the cultivated area in Shahabad district. A large portion of the cultivated area is irrigated by the canals.

In Shahabad district, wells for agricltural use are on the increase as described below.

Actual number of wells existing in the district could not be confirmed during the present survey. However, data of Arrah sub-division, shown in Table 7-3, were provided to the mission by the Minor Irrigation Department. The table shows the number of wells drilled under the control of the said department during the period from 1950/1951 to 1970/1971. As is clear in the table, a total of 1,903 wells were drilled, of which tube wells numbered only 11 since 1961/1962. As compared with this, open boring with strainer (abbreviated O.B.S.) numbered 713 cases and registered a remarkable increase from 1966/1967 to 1967/1968 as s seen in Fig. 7-1. Further, open boring without strainer marked the largest number of 1,179 cases (open boring without strainer is abbreviated to O.B. Both O.B.S. and O.B. are similar in stlucture to Type 1 shown in Fig. 9-1. The two differ from each other in that the former has strainers installed in the tube while the latter has no strainers).

Numbers of wells drilled in Shahabd district during the period from 1960/1961 to 1971/1972 are shown in Table 7-4. As shown in this table, about 6,000 new wells came into existence during the said period but most were drilled by O.B. or O.B.S., with tube wells counting only 35. However, the number of wells per sub-division is maintained constant.

Fig. 7-1 INCREASING CURVE OF WELLS IN ARRAH SUB-DIVISION
(1950-1951 to 1970-1971)



Source: Irrigation Department

Table 7-3 NUMBER OF WELLS

M.I.D.

No.	Name of block	50–51 A	50–51 B	50–51 C	51–52 A	51–52 B	51–52 C	52–53 A	52–53 B	52–53 C	53–54 A	53–54 B	53–54 C	54–55 A	54–55 B	54–55 C	55–56 A	55–56 B	55–56 C	56–57 A	56–57 B	56–57 C
1	Udwantnagar			7			8			4			2			3			2			2
2	Charpokhari			6			3			4			4			1			3			3
3	Piro			5			25			5			4			3			15			1
4	Tarari			3			3			7						1			1			2
5	Jagdishpur			17			17			2			6			4			5			5
6	Sahar			11			27			2			1			1			4			
7	Arrah			12			22			8			5		1	7		3	8		2	2
8	Barhara			1			1												1			
9	Koilwar			15			11			5			3			1			2			1
10	Sandesh			7			3												3			1
11	Behea			9			3			2								1	2			
12	Shahpur			19			10			6									1		1	
Σ				112			134			45			25		1	21		4	47		3	17
Total			112			246			291			316			338			389			409	

No.	Name of block	57–58 A	57–58 B	57–58 C	58–59 A	58–59 B	58–59 C	59–60 A	59–60 B	59–60 C	60–61 A	60–61 B	60–61 C	61–62 A	61–62 B	61–62 C	62–63 A	62–63 B	62–63 C	63–64 A	63–64 B	63–64 C
1	Udwantnagar			2		1	8		1	3			3		5	5			8			4
2	Charpokhari			3			7			1						5			6		1	4
3	Piro			2			4			1			8			5			4			1
4	Tarari			7			10			3		1	6			2						1
5	Jagdishpur			14			6		1	9			9			2			4		1	5
6	Sahar			12			1			7			12			2						3
7	Arrah		7	7		2	2		12	13		6			3	1		3	4		5	
8	Barhara		1						1	1		2		2				7			1	
9	Koilwar			7		4	4		2	8		1	4		1	3		10			2	4
10	Sandesh			2			5			2			3			3		1	2			
11	Behea		1			1	4		4	5					3				1		2	1
12	Shahpur		3	5		3	1		3	18		5	9		5				3		2	3
Σ			9	61		11	52		24	71		15	54	2	17	28	1	22	32		14	26
Total			479			542			637			706			753			808			848	

No.	Name of block	64–65 A	64–65 B	64–65 C	65–66 A	65–66 B	65–66 C	66–67 A	66–67 B	66–67 C	67–68 A	67–68 B	67–68 C	68–69 A	68–69 B	68–69 C	69–70 A	69–70 B	69–70 C	70–71 A	70–71 B	70–71 C
1	Udwantnagar			1		3	3	1	6	5		13	10		1	8			2		6	3
2	Charpokhari			1						3		7	4			11			1			1
3	Piro		2	5			3		3	11		13	11		1	1		1	4			
4	Tarari			11						10			11			3		1	1			
5	Jagdishpur		2	11		9	14		19	20		69	9		14	5			9		3	
6	Sahar			8			7			19			30		1	17			13			3
7	Arrah		3			7	1		22			39	5	1	10	2		5	1		33	1
8	Barhara		3		1	15			12			41			18			3		1	6	
9	Koilwar		11	9		12	8		25	11	2	31	11		10	5		2	1			
10	Sandesh			10		4	9			21	1		23			21			5			
11	Behea					2			3			55	4		2	9		1	6		12	
12	Shahpur								5			10			5	1		5	1	1	6	
Σ			22	56	1	52	45	1	95	100	3	278	118	1	62	83		18	44	2	66	8
Total			926			1. 024			1. 220			1, 619			1, 765			1, 827			1, 903	

A: Tube well
B: Open boring with strainer (O. B. S.)
C: Open boring without strainer (O. B.)

=

Number of wells
A ------- 11
B ------ 713
C ---- 1, 179

Total 1, 903

Table 7-4 INCREASE OF TUBE WELL IN SHAHABAD DISTRICT
(1960/1961 - 1970/1971)

Item	Arrah	Buxar	Sasarum	Bhabua	Shahabad
Tube well	17	16	2	0	35
Open boring with strainers 1	726	682	638	60	2,106
Open boring without strainers 2	529	1,134	871	1,303	3,837
Total	1,272	1,832	1,511	1,363	5,978

Remarks:
/1 and /2: Refer to the following page.

Calculation worked out from the data shown in Tables 7-3 and 7-4 shows that the number of private tube wells drilled in the district during the period of 1950/1951 to 1971/1972 is about 9,200 (= 1903/1272 x 5978). This figure, however, represents only those wells which are estimated to have been drilled under the control of the Minor Irrigation Department (hereafter called "M.I.D.") and its predecessor, Agricultural Department. There are found, besides these, privately drilled wells and state tube wells drilled under the control of the Lift Irrigation Department (hereafter called "L.I.D.") (About 270 state tube wells were drilled in Arrah sub-division alone. Estimated total of state tube wells in whole Shahabad district is about 1,000) In addition, there are distributed many open shallow wells having a diameter of 1 to 3 m and walls built by piling. Manual labour or animal power is employed for pumping up water from these open shallow wells. Number of these wells is not known.

During the drought period of 1965/1966 to 1966/1967, water shortage was so acute that even drinking water was not sufficiently available. This gave rise to the drilling of various tube wells by the Public Health Engineering Department (hereafter called "P.H.E.D.").

Table 7-5 shows the power consumption for these tube wells. In the total power consumption recorded in 1969/1970, irrigation accounted for 11.7% (23,200,000 KWH). During the period from 1967/1968 to 1969, power consumption for irrigation rose to 126 per cent, marking the second largest increase after public lighting. The increase is quite conspicuous because the country's total power consumption declined to 96% during the same period. It may as well be added that the increase ratio of all tube wells during this period was 113 per cent. Thus, the increase ratio of power consumption is slightly larger than that of tube wells, suggesting that the pump operation hours was extended to some extent.

Table 7-5 POWER CONSUMPTION BY PURPOSE

Purpose	① 1967/68	② 1968/69	③ 1969/70	④ Percent-of (%)	⑤ ②/①	⑥ ③/①
Domestic and commercial	8,69	8,84	9,14	4,6	1,02	1,05
Industrial (up to 650)	12,50	12,48	13,04	6,6	1,00	1,04
Industrial (abobe 650)	165,85	160,19	151,69	76,4	0,97	0,92
Public lighting	0,26	0,35	0,38	0,2	1,35	1,46
Irrigation	18,46	22,07	23,20	11,7	1,20	1,26
Public water works and sewage pumping	1,05	1,09	1,07	0,5	1,03	1,01
Total	206,91	205,02	198,52	100,0	0,99	0,96

Remarks: Quoted from reference data No. 2.

7.2 Organizations for Agricultural Groundwater Development

Agricultural groundwater development is undertaken by M.I.D. and L.I.D. Organization and activities of these government offices in Bihar state are as outlined below.

7.2.1 M.I.D.

When well drilling is applied for by farmers and necessary fund is available (if fund is covered by collateral loan, the security offered is evaulated by Land Mortgage Bank), drilling and tube insertion work is conducted directly by M.I.D. Though the drilling dimater ranges from 3 to 6", most wells have a diamter of 4". Tube wells with a diameter fo 6" have come to be drilled recently though limited in number. A 60HP rotary machine (truck-mounted digging machine) is employed for drilling tube wells having a diameter of 6" as well as tube wells with 4" diameter which are to have a depth of 200 ft or larger. Tube wells with 4" diameter which are to have a depth of less than 200 ft are drilled by human labour using a percussion type hand machine. Drilling work is commissioned to a private agency when its execution is beyond the M.I.D.'s capacity. Drilling cost payable to such private agency is stipulated by the state government. Pumping test is conducted by the applying farmers. When electricity is used as motive power, wiring work is carried out by the Electric Board. Cost of wiring work, electric rate and other expenses are shown in Reference Data 1. When a diesel engine is to be used as power source, M.I.D. makes necessary arrangements for its provision. Pump house construction and piping work are undertaken by farmers themselves.

When the benefited area is smaller than 5 acres, subsidy is provided to cover 25 per cent of the cost of drilling and tube. Further, 25 per cent of total cost is subsidized irrespective of the size of benefited area if pumps with a diesel engine are to be installed. In case fund is available, it takes about two months from the time of application to the completion of well, and this period becomes longer to about three months if the drilling work is conducted on security. As a rule, wells are dug at intervals of more than 1,000 ft if their diameter is 4" and more than 1,500 ft if the diameter is 6".

7.2.2 L.I.D.

In principle, L.I.D. carries out drilling work outside the area benefited by canals in accordance with the plan mapped out by the state government. It is often the case, therefore, that the well site is selected near the canal tail end. When the drilling work is completed, L.I.D. carries out pumping and water distribution by the request of the neighbouring farmers. Needless to say, tube wells dug by L.I.D. are the property of the state government, and water is distributed on charges which are determined by the kind of crops and irrigation frequency as shown in Table 4-16.

Pumping and water distribution work is controlled by government operators, and prepayment system is applied for collection of water charges. L.I.D.'s wells have a drilling diameter of 6" or larger (8" or larger for wells drilled in and after 1967) and their depth ranges from 200 to 300 ft for the most part. Actual drilling work is conducted by private companies having public nature like Ingra under a contract concluded with L.I.D. Standard cost required for tube well drilling and pump installation is shown in Reference Data 2. The mission learned that the state government has the intention to give high priority to increased installation of private tube wells in future.

7.3 Problems of Groundwater Utilization

Technical as well as maintenance and operation problems involved in groundwater utilization are enumerated below.

(1) At present, systematic and effective pump operation is made difficult by the unstable pwer supply condition. Efforts are therefore being made for assuring stable and cheap power supply to meet the demand in agricultural as well as non-agricultural sectors.

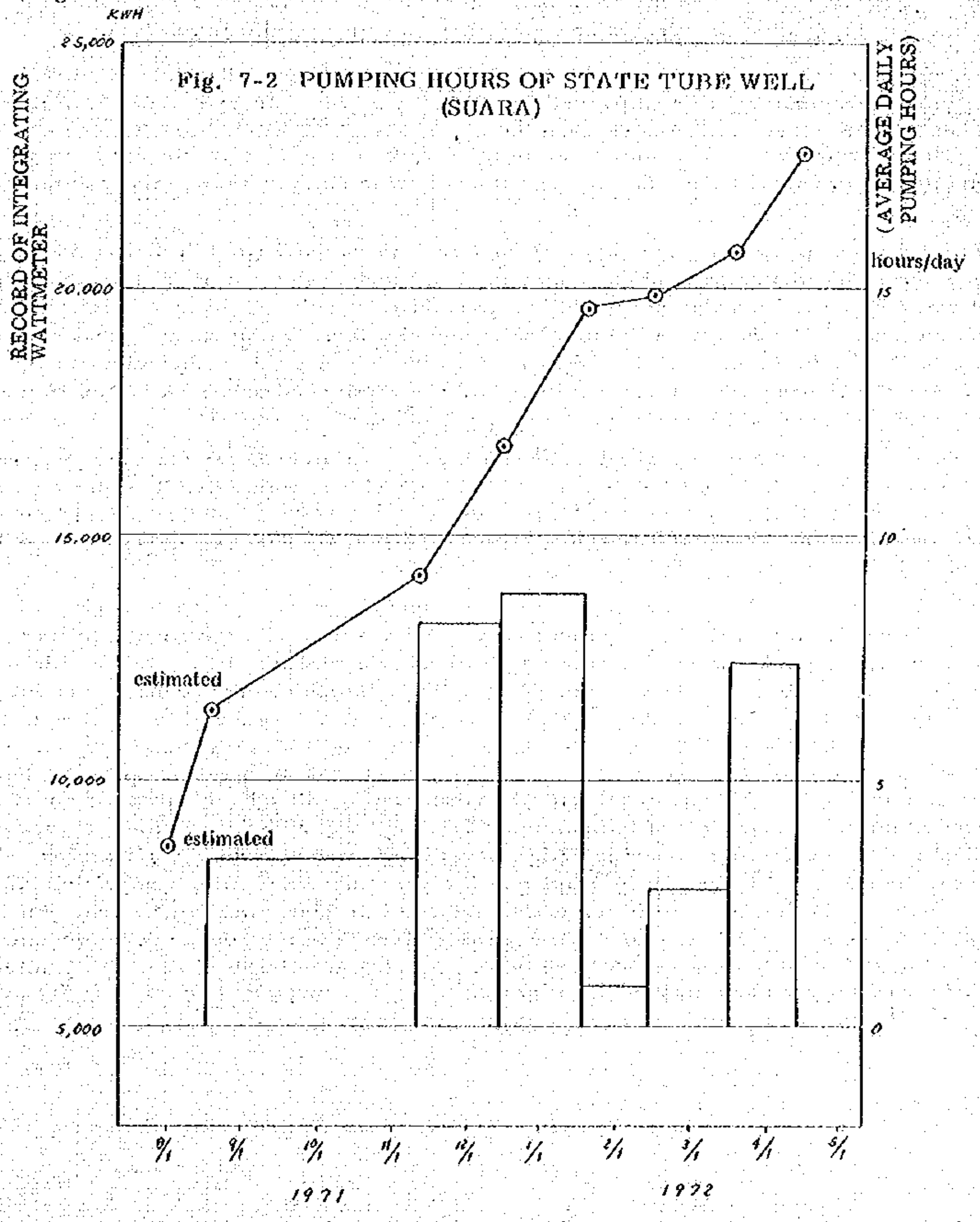
In areas where commercial power supply is stabilized and available at low cost, various motor-driven pumps are installed. Pumping hours varies partly by the size of benefited area. In case of some of private tibe wells found the daily pumping hours ranges from 3 to 4 hours on the average. It is known that the daily pumping hours of some of state tube wells is about 3 to 9 hours (See Fig. 7-2).

In areas where commercial power supply is not stabilized, diesel engine-driven pumps are employed and in many cases, they prove more efficient than the motor-driven pumps. About 20 per cent of all tube well pumps are equipped with a diesel engine and the remaining 80 per cent are driven by commercial power.

(2) All private tube wells and some of state tube wells are equipped with a centrifugal pump. Since centrifugal pumps become inoperative when the suction head exceeds 7 to 7.5 m, they are often installed at a depth of 2 to 4 m beneath the ground surface so as to decrease the suction head. Pumps are set in open wells only in exceptional cases. Ordinarily, they are installed in an underground pump house and connected to the open well with the suction pipe. The underground pump house has concrete walls to prevent groundwater intrusion. Needless to say, the pump site is selected after a careful survey so that groundwater may not intrude even when it has a high level. In Flooded Area, maintenance service is made very troublesome because the motor and part of the pump must be removed from the pump house in the rainy season when flood water intrudes from above.

Centrifugal pumps are directly coupled with the tube well pipe, and this makes it impossible to detect the groundwater level and its fluctuation.

(3) Most of state tube wells are equipped with a bore hole pump and some with a centrifugal pump, and electric power is used for their operation. Due to power shortage and resultant service interruption, these pumps are not used efficiently for supplying water at the right time. Another factor hampering their timely operation is the fact that they are run by government operators and not by farmers. It is therefore hoped that efforts will be directed towards assuring stable power supply and that the operators will put themselves in the place of farmers in performing their duties.



Chapter VIII Agricultural Water Use and Hydro-geological Condition in Sub-centre Areas

8.1 Natural Condition in Shahabad District

As shown in Fig. 4-3, the six sub-centres are distributed along the Sone, with Suara Sub-centre (No. 1) located in the area close to the skirts of hilly area and Kulharia Sub-centre (No. 6) found near the Ganga. Of these six sub-centres, Sub-centre No. 2 is not yet established though it is planned to be located in Sasaram Sub-division. Katar Sub-centre (No. 3), Garhani Sub-centre (No. 4), Ekauna Sub-centre (No. 5) and Kulharia Sub-centre (No. 6) are all located in Arrah Sub division.

The alluvial fan in which these six sub-centres are distributed has an elevation of 50 to 150 m and a mild surface slope (approximately 1/1, 700). This mild surface slope, however, may be considered fairly steep when compared with the Ganga's river slope which is about 1/13, 000 between Arrah and estuary. The area extending on the left bank side of the Sone in the southern hilly area is geologically composed of sand stone of the Cambrian and Pre-cambrian periods for the most part, so that when boring is conducted in the piedmont district, the top often reaches the bed-rock. In the area stretching on the right bank side of the river, on the other hand, gneiss and granite of the Pre-cambiran era prevail.

In this southern area which is called "Hilly Area" or "Crony Drought Effected Area," agricultural development is being pushed forward at present. An extensive alluvial fan stretches on both sides of the Ganga. On the right bank side, the fan extends over a width of about 120 km, whereas the distance from the left bank of the river to Silwalik Range is as long as about 140 km. Hence, the fan constitutes a wide plain having a total width of about 260 km.

The area extending along the banks of the Ganga is the so-called "Flooded Area" which is subjected to inundation and submergence in each flood season. Fig. 4-3 showing the boundary of Flooded Area was preapred just for convenience's sake because its clear delineation is not possible by reason of the fact that river terraces can be hardly found though the surface of the alluvial fan is eroded 10 to 15 m by the existing river surface of the Ganga and their river bed (Topographic difference of 1 to 2 m is observed only locally and considered assignable to the flank erosion ensued from the flooding of the Ganga).

Kuharia Sub-centre is situated in Flooded Area. In this area, the surface of alluvial fan is eroded about 5 m by all the small rivers. Therefore, water distribution from rivers to paddy fields is difficult unless canals or a network of a barrage and canals are constructed. For this reason acreage of natural river water irrigation area is not calculated (See Tables 7-1 and 7-2).

Alluvial fan not including Flooded Area is called "Canal Area." Canal Area is a flat plain with a gradient of about 1/1, 700 and embraces no hilly areas. Arrah canal and its branch canals and distributaries were constructed in the mid-nineteenth century when India was under the British rule. It is because of the wide distribution of these canals that the area is called Canal Area. In 1965, improvement of Arrah canal was effected together with the construction of its intake barrage, Sone barrage, with the necessary fund provided by IBRD. At present, drilling of wells is being promoted in Canal Area to meet the growing demand for water (See Table 7-3) in parallel with the construction of High Level Canal which is intended chiefly for irrigation of the peidmont area in Bhabhua Sub-division. However, development of new water sources for High Level Canal (through dam construction, etc.) is not yet undertaken. It leaves little doubt that the water shortage in the paddy field area commanded by Arrah canal will become acuter than at present when High Level Canal is completed. Establishment of an overall and district-wide water source development is therefore urgently called for. Locations of sub-centres are shown in Fig. 4-3 and the existing state of water sources and outline of the proposed water source development areas are shown in Table 8-1.

Table 8-1 OUTLINE OF WATER SURCES IN SUB-CENTRE AREAS

No. Block Sub-centre Elevation	1 Dehri Suwara Apprex. 105 m (Apprex. 350')	2 Gikramanj Under plan Approx. 90 m (Approx. 300')	3 Piro Katar Approx. 80 m (Approx. 270')	4 Charpokhari Garhani Approx. 70 m (Approx. 240')	5 Udwamagar Ekauna Approx. 60 m (Approx. 200')	6 Koilwar Kulharia 53 - 56 m (178 - 188')
Surface water	Water is drawn from the Sone because the area has a higher elevation Than High Level Canal and is also far from the main canal. Canal water utilization is not therefore possible.	No survey was conducted since the sub-centre site is not selected yet.	The eastern half of the area cannot be irrigated because its elevation is 30-50 m higher than in the surrounding area. In the wester half, village channels and field channels are distributed but water is deficient due to limited flow from upstream.	Water is scarce though Ahar and village channel are distributed in the southern part. In the surrounding area, irrigation water is pumped up from rivers. (10 HP pump with a 6" suction pipe used for pumping up about 0.045 m^3/sec of water. Head is 8 m)	Water falls short of demand since the area is located near the tail end of the canal system. Development of Ahar is observed outside the area.	Surface water utilization is not feasible because the area is far from the tail end of the canal system.
Ground-water	The area is irrigated by 27 P. T. W. I. and 1 S. T. W. I. Not much groundwater is available because the area is close to the mountainous district.		There are 2 P. I. W. I. and 2 P. O. W. I. Groundwater is relatively rich because the area is in the central plain.	There are 4 P. T. W. I. but all are shallow wells not capable of continuous operation. If tube wells are drilled to a larger depth, abundant groundwater will become available because the area is in the central plain. The one S. T. W. I. is rarely put in operation.	There are only 2 P. T. W. I. Groundwater is copious because the area is in the central plain.	The area is irrigated by 3 P. I. W. I. and 1 S. T. W. I. Besides these, there is 1 P. O. W. I. used for supplementary water supply. Groundwater is rich since the area is in the central plain. Many wells are found in the surrounding area.
Comment on future water source development	Utilization of deepseated groundwater is considered advisable.	No studies made yet.	Groundwater utilization is advisable, but studie should also be made for surface water utilization.	Surface water utilization should be studied with attention directed to groundwater utilization.	Surface water utilization is considered suitable, studies should be made for groundwater utilization as well.	Groundwater utilization is suitable, but studies should also be made for storing water by circle method.
Preliminary design	No studies made yet.	No studies made yet.	Groundwater utilization.	Groundwater utilization.	No studies made yet.	Groundwater utilization.

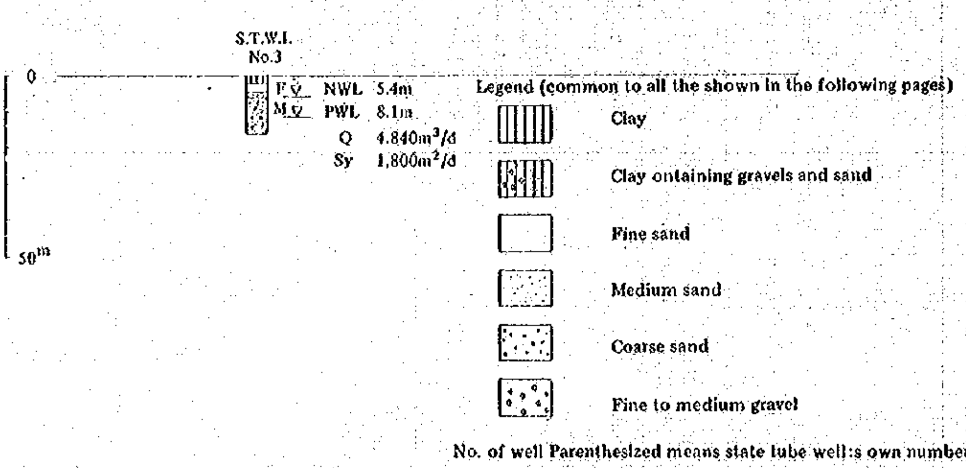
8.2 Suara (No. 1)

Suara Sub-centre has been engaged, since 1955, in the extension of intensive agriculture covering entire Surara village. Though the sub-centre area is close to the hilly area, it is favoured with relatively rich groundwater sources because the Sone river flows nearby. In this area, one each of private tube well for irrigation (hereafter abbreviated to "P. T. W. I") and state tube well for irrigation (hereafter abbreviated to "S. T. W. I. ") are employed for practical purpose. Distribution of tube wells and their size are shown in Fig. 4 and Table 8-1 respectively.

Surface water irrigation entails difficulties in this area because the elevation of the area is higher than High Level Canal which draws water from the Sone. Though water is pumped up from as many as 28 tube wells at present, some parts in the area still suffer water shortage. All private tube wells have an underground pump house, and their depth ranges from 17 to 20 m and diameter from 3 to 4". Water is pumped up by centrifugal pumps. The pump capacity, though not measured actually, is estimated at 0. 005 to 0. 01 m^3/sec. A standard tube well commands an area of 10 to 12 acres for Rabi crops, about 5 acres for summer crops and about 10 acres for Kharif crops.

The only S. T. W. I. found in the area has a depth of 16. 5 m, diameter of 12", and 12. 5 HP bore hole pump is used for pumping up 0. 056 m^3/sec of water. Drawdown is about 2. 7 m and specific yield is 1, 800 m^2/day (4, 840 m^3/day ÷ 2. 7 m = 1, 790 m^2/day). Past records indicate that the average irrigation area covered by this tube well over the five year period from 1961 to 1965 was 228 acres for Rabi crops, 67 acres for summer crops and 212 acres for Kharif crops. The drilling record of the same tube well shows that a clayey layer reaches to a depth of 2 to 3 m from the ground surface, overlying a sand layer of fine and medium grain size which extends to a depth of 6 m. The sandy layer is underlain by a gravel layer extending down to a depth of 16. 5 m below the ground surface. (See Fig. 8-2) This conspicuous development of gravel layer is considered assignable to the fact that the well site is in the piedoment district upstream of the Sone. In no other sub-centre areas can be observed so remarkably developed gravel layers. Amount of water pumped and water quality were measured only at the said S. T. W. I. (See Table 8-2). The water temperature was 28. 7°C and conductivity 2. 95/u/cm (equivalent to 0. 0024 mol/1 when converted to KC1).

Fig. 8-2 SUARA SUB-CENTRE



8.3 Katar (No. 3)

Since 1971, Katar Sub-centre has been pushing forward extension of intensive agriculture in an area of 65 acres and it is planned that this area will be expanded to 100 acres in the near future. As shown in Fig. 8-3, village channels are distributed to the southern part of the area, with fairly well developed village channels connected with them. However, the area suffers water shortage due to the limited discharge from upstream.

There is installed one P. T. W. I. (No. 4) which has a depth of 52. 5 m and diameter of 0. 10 m and is equipped with a 5 HP centrifugal pump by which 0. 0085 m^3/sec (880 m^3/day) of water is pumped up. Tube well No. 2 located in the south outside the area is intended for public drinking water supply. It has a depth of 143 m and diameter of 0.457 m, and is equip equipeed with a 22.5 HP bore hole pump which is operated about 4 hours a day for pumping up 0.05 m^3/sec of water. Natural water level and pumping water level of this tube well are 6.30 m and 7.9 m respectively. All the other wells are shallow wells having an average depth of 4 to 6.3 m. Of these shallow wells, No. 5 and No. 6 are for agricultural use, but seem to be put im use only in an emergency because they have neither power equipment nor a pump.

Fig. 8-4 whows the boring log and data of electric resistivity survey (conducted at two points) of S.T.W.I. (No. 2). (Refer to Reference Data 3 for ρ - a curve)

P.H.E.D.'s boring log indicates that sand layers are inserted between depths of 35 - 40 m, 54 - 66 m, 88 - 92 m and 107 - 127 m below the ground surface, forming good aquifers. Of these sand layers, the one stretching between 107 and 126 m below the ground surface ranges from medium to coarse in grain size and therefore constitutes a particularly good aquifer.

Layers other than these sand layers are composed of brown clay and are believed to form pressured layers. Clay layers are known to occupy a greater ratio in this area than in the proximity of Kulharia Sub-centre. According to the pumping test conducted upon completion of the well, the amount of water pumped is 5,680 m^3/day at a drawdown of 5.5 m, so th that the specific yield is as large as 1,060 m^2/day. P.T.W.I. (No. 4) is said to have a depth of 5.5 m. It is possible that water is pumped up from the second aquifer at this well, but this is not ascertained due to the lack of detailed information.

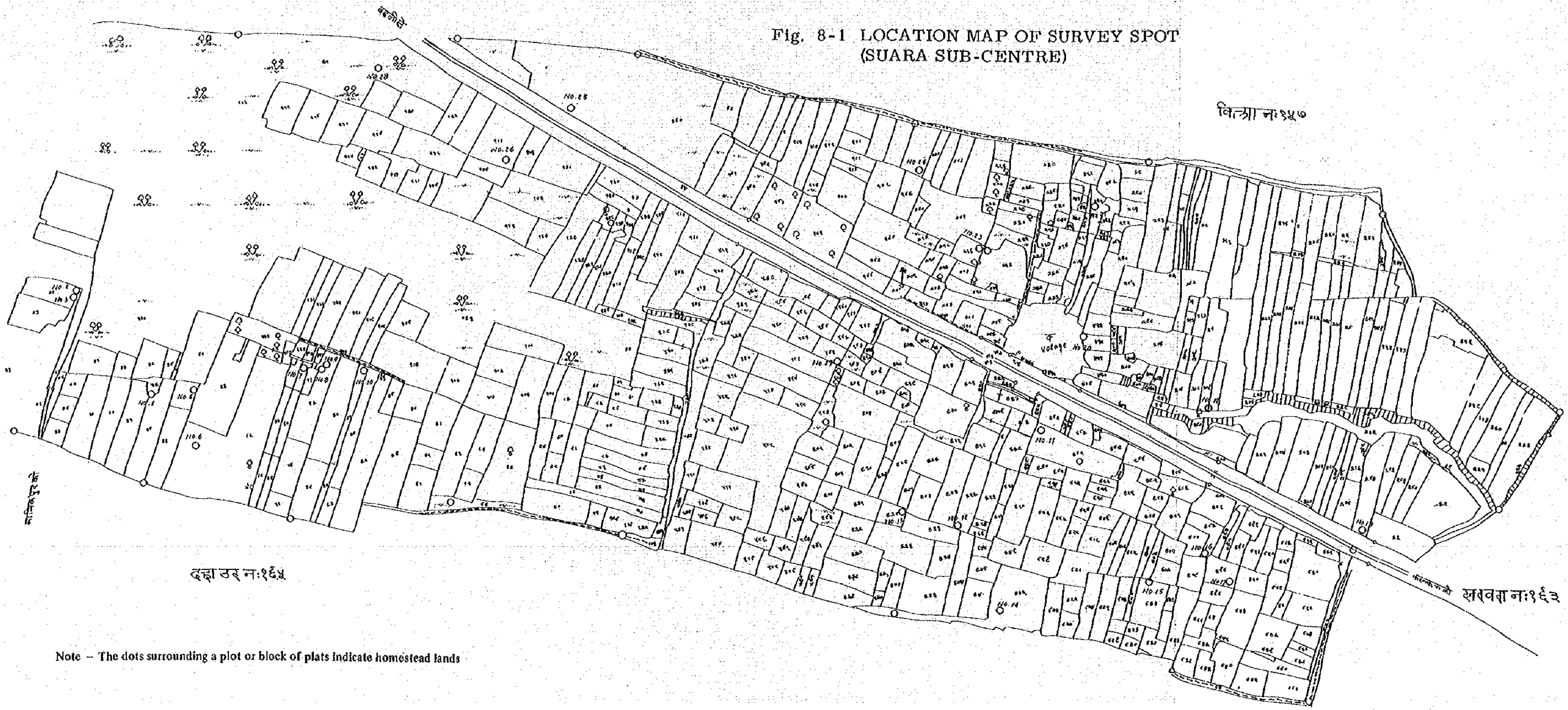
The record of electric resistivity survey indicates that the specific resistance ranges from 45 to 50 Ω - m above the depth of 70 - 80 m and from 10 to 10 Ω - m below it.

Some difference in water temperature is observed between deep wells and shallow wells, the former (30 m deep) showing a temperature range of 27 - 29°C and the latter 22 - 25°C. Well No. 3, however, shows the same water temperature as deep wells though it depth is only 5.9. It is probable that this well is of O.B.S. or O.B. type. As for electric conductivity, there can be observed little difference between the two types of wells, though deep wells show slightly lower values than shallow wells as shown in Table 8-2.

Since surface water availability is limited in the terminal parts far from the branch canal, it is advisable that endeavours be made for development of groundwater sources. It is not considered that any knotty problemes will arise from the new groundwater utilization because the area is not developed in deep well construction.

The norghern half of the area is somewhat higher in elevation than the remaining parts so that its irrigation by field channels is made difficult.

Fig. 8-1 LOCATION MAP OF SURVEY SPOT (SUARA SUB-CENTRE)



Note – The dots surrounding a plot or block of plats indicate homestead lands

Fig. 8-3 LOCATION MAP OF SURVEY SPOT
(KATAR SUB-CENTRE)

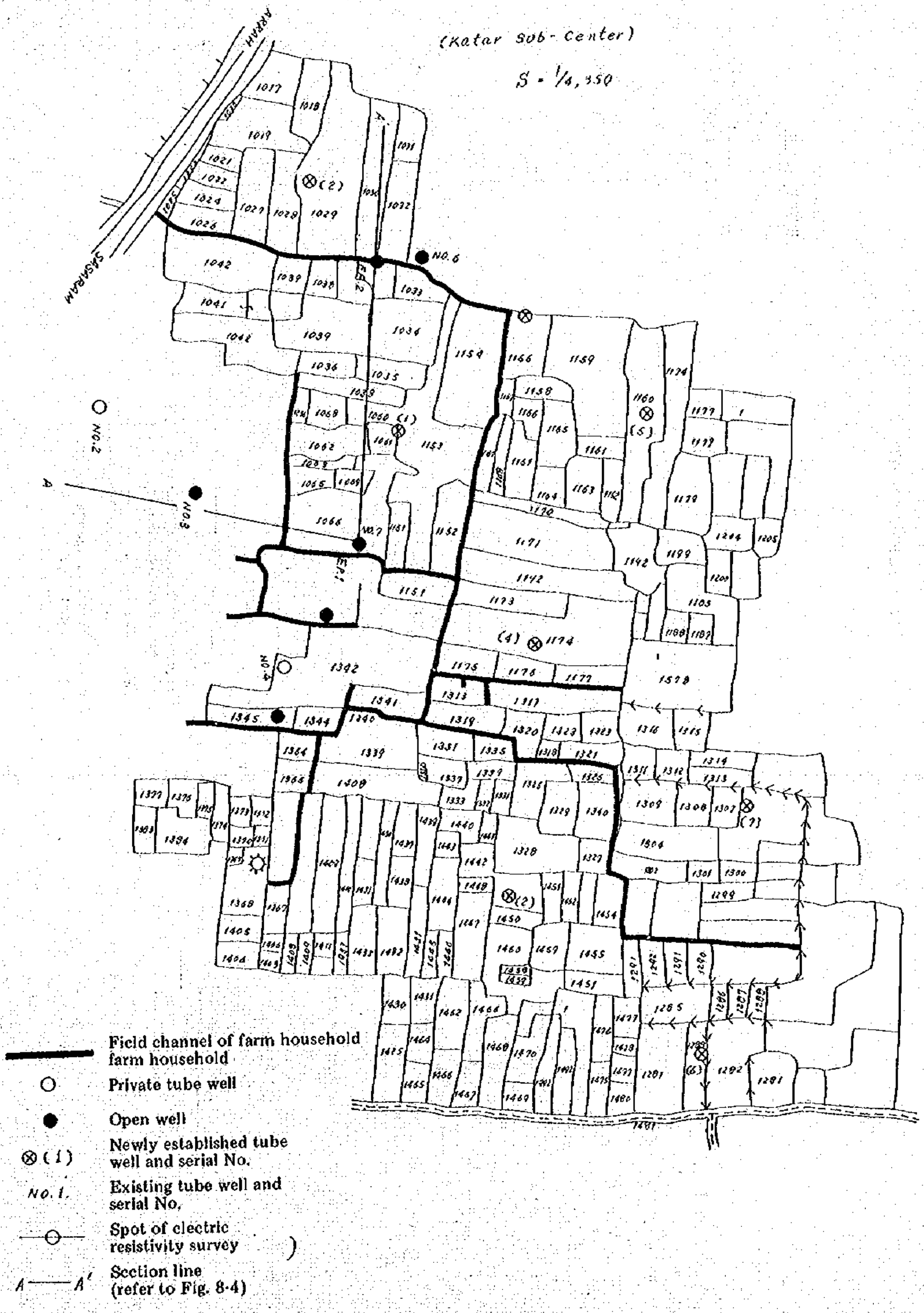
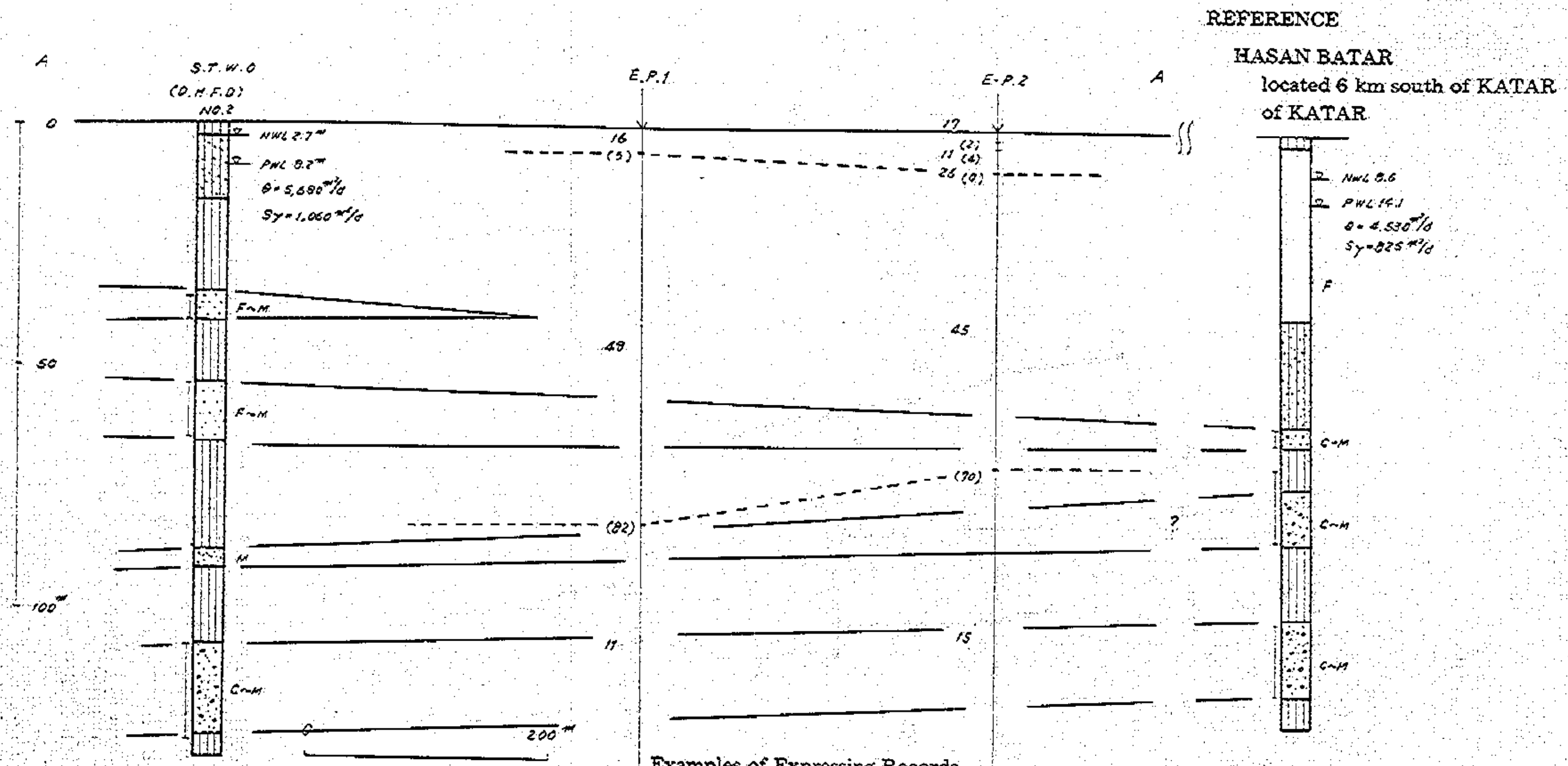


Fig. 8-4 KATAR SUB-CENTRE



Examples of Expressing Records of Electric Resistivity Survey

(82): Border line of specific resistance value R_1 unit: m

48: Specific resistance value; unit: Ω-m

Table 8-2

No. of Well	Droup	Diameter (m)	Depth (m)	Kind of Pump	Horse Power (HP)	Amount of Water Pump (m^3/sec)	Amount of Water Pump (m^3/day)	Height (m)	N.W.I.	P.W.I.	S.	Water Temprature (°C)	Electric Conducti-vity	Electric Meter	Electric Meter (KW)	Benefited Acreage: Rabi	Benefited Acreage: Summer (garma)	Benefited Acreage: Kharif
KULHARIA SUB-CENTRE (No. 6)																		
1(10)	S.T.W.I.	0.150	69	S		0.0483	4,170	0.42	5.58	–	–	27.7	460	079923.0	(4/ 7)	100	75 (target)	125
2	P.O.W.	2.0	8.2	none	none	(For drinking and miscellaneous use)		0.30	5.62	–	–	24.6	1,310	–		–	–	–
3	P.O.W.	1.58	7.5	none	none	–do–		0.20	5.70	–	–	24.3	750	–		–	–	–
4	P.W.W.	2.00	7.3	none	none	–do–		0.25	4.50	–	–	22.2	660	–		–	–	–
5	P.T.W.I.	0.10	75.6	C	5	0.0149	1,290	–	–	–	–	27.5	500	9081.0	(3/30)	11~12	4~5	20
6	P.O.W.	1.85	6.7	none	none	(For drinking and miscellaneous use)		0.40	2.20	–	–	(20.6)	(450)	–		–	2	–
7	P.T.W.I.	0.1?		C	5	0.0067	580	0.70	1.68	1.70	30 min 0.02	23.6	540	066942.9	(4/ 3)	10	3	10
8	P.T.W.I.	0.075	54.0	C	5	0.0152	1,320	0.30	2.20	–	–	22.2	750	559242	(4/13)	10	25	15
9(21)	S.T.W.I.	0.15	81.5	C	15	0.0257	2,220	–	–	–	–	27.6	435	2069.55	(4/ 7)	125	10	0 By canal
10(17)	S.T.W.I.	0.15	82.5	C	12.5	0.0355	3,050	–	–	–	–	27.4	520	88603.6	(4/ 7)	175	50	60
11(11)	S.T.W.I.	0.15	80.0	T	15	0.0359	3,100	–	–	–	–	27.8	510	7854.3	(4/ 7)	175	50	150
12(19)	S.T.W.I.	0.15	75.6	S	12.5	0.0399	3,450	0.90 ±	40.6	7.00	115 min 2.94	27.6	542	9819973	(4/ 7)			150
CARHANI SUB-CENTRE (No. 4)																		
1	O.B.S.	2.95 0.075	8.55 32.0	C	5	(0.0112)	(970)	0.20	(6.88)	(6.90)	5 min (0.02)	26.5	630	03570515	(4/11)	13	2	8
2	O.B.S.	1.90 0.075	8.25 30.7	C	5	(0.0079)	(576)	0.20	(5.57)	(7.05)	min (2.48)	27.7	643	0774.45	(4/11)	3	1	8
3	O.B.S.	1.85 0.075	7.80 30.4	C	5	0.0057	504	0.70	2.92	(6.29)	57 min (3.37)	26.7	590	–				
4	O.B.	2.08 0.075	7.00 30.5	none	none	–	–	0.30	1.78	–	–	(27.7)	(570)	–		10	2	13
5	S.T.W.I.	3.305	106.0	T	15	(0.064)	(5,340)	0.60 ±	2.88	(6.34)	6 min (3.46)	27.4	560	00007.0	(4/21)		1	
KATAR SUB-CENTRE (No. 3)																		
1	P.O.W.	1.48	5.3	none	none	–	–	0.40	3.60	–	–	–	–	–		none	none	none
2	S.T.W.D.	0.457	143.0	T	22.5	(0.050)	(4,320)	0.60 ±	6.30	7.90	30 min 1.6	27.6	420	00327.2	(4/17)	In use for drinking water supply, daily pumping.		
3	P.O.W.	1.10	5.9	none	none	–	–	0.50 ±	3.25	–	–	28.8	315	–		none	none	none
4	P.T.W.	0.10	52.5	C	5	0.0085 0.010	880	0.30 ±	Unknown	–	–	27.0	190	01722.6	(4/17)	8~10	5	hours-4 his
5	P.O.W.I.	1.78	5.2	none	none	–	–	0.40	1.80	–	–	22.4	530	–		–	–	–
6	P.O.W.I.	2.05	6.3	none	none	–	–	0.60	2.60	–	–	23.5	440	–		–	–	
7	P.O.W.O.	1.00	3.9	none	none	–	–	0.00	2.95	–	–	25.3	420	–		none	none	none
SUARA SUB-CENTRE (No. 1)																		
1	O.B.S.	0.075	16.8	C	5	–	–	0.20 ±	5.37	–	–	(25.5)	(388)	12169.78	(4/15)	12	5	10
2	P.O.W.	2.33	9.2	none	none	–	–	0.65	6.05	–	–	(24.0)	(1,340)	–		none	none	none
3	S.T.W.I.	0.305	16.5	T	12.5	0.056	4,840	1.20 ±	5.43	8.12	25 min 2.69	28.7	295	022970.4	(4/15)	228	67	212
EKAUNER SUB-CENTRE (No. 5)																		
1	P.O.W.	1.93	6.40	none	none	–	–	1.20	2.98	–	–	22.2	633	–		–	–	–
2	P.T.W.I.	0.064	27.45	C	5	–	–	0.00	–	–	–	–	–	Utilized also for rice milling Not necessary		5	15	10

Notes to Table 8-2:

1. No. : Parenthesized numbers are the serial number of wells belongine to L. I. D. (Lift Irrigation Department).

2. Abbreviation of ownership classification:

S. T. W. I.	State Tube Well for Irrigation
P. T. W. I.	Private Tube Well for Irrigation (incl. O. B. S. and O. B.)
P. O. W. I.	Private Open Well for Irrigation
S. T. W. D.	State Tube Well for Drinking Water
Pu. O. W.	Public Open Well
Pu. O. W. O.	Public Open Well for Other Uses

3. Drilling diameter: Tube diameters are shown in meter for all wells excluding P. O. W. I. and Pu. O. W.

4. Depth: In case of P. T. W. I. whose drilling depth differs from tube insertion depth, the former is adopted.

5. Abbreviation of the kind of pump:

S	Submergible pump
C	Centrifugal pump
T	Turbine pump (bore hole pump)

6. Amount of water pumped: Amount of water pumped is shown only for those tube wells using power for pumping operation. Parenthesized values indicated estimated amount of water.

7. : Height from the bench mark for water level measurement.

8. NWL: Natural water level (depth below the ground surface).

9. PWL: Pumping water level (depth below the ground surface).

10. Temperature: Parenthesized values indicate temperatures measured while pumping operation is suspended.

11. Electric conductivity: Parenthesized values are the conductivity measured while the pumping operation is suspended (Not converted to values at 18°C).

12. Electric meter: Readings of the integrating wattmeter are shown with the date of measurement indicated between parentheses. All dates of measurement coincide with those of water level measurement.

13. Benefited area: Figures involve substantially large error because they were obtained through interviews with the exception of Suwara No. 3.

8.4 Garhani No. 4

Garhani Sub-centre has been engaged in the extension of intensive agriculture since 1969 in an area of 53 acres. This area is planned to be expanded to 100 acres after 1972. As seen in Fig. 8-5, Ahar is established in the southern part of the area, with the terminals of distributaries found in the surrounding area. However, since water supply is not sufficient, the area has 4 P. T. W. I. s. These wells were drilled in the 1967 drought year in the already existing shallow wells, so that the upper part of each well constitutes a shallow well having a diameter of 1. 9 - 3. 0 m and a depth of 7. 8 - 8. 6 Boring was conducted down to a depth of 30 - 50 m below the bottom of the shallow well, but the tubes were set only to a depth of about 5 m below the bottom. Hence, these wells present a typical example of O. B. Tubes with strainer are not installed to the drilled depth. The reason is that the brass strainer for sand layer is costly and that pumping up a large amount of water with the expensive strainer is not required because the well owner does not hold a large cultivated land. The 3"ϕ tube of these wells is not directly connected with the pump suction pipe, but has the structure shown in Fig. 8-6 (All P. T. W. I. s in other ares have their tubes connected directly with the pump suction pipe). All pumps are the 5 HP centrifugal pumps installed in an underground pump house approximately 2 m below the ground surface.

When water is pumped up from such tube wells, the water level declines about 3, 5 in about an hour (See Fig. 8-7) so that pumping operation must be suspended. In case of Well No. 4, which is a P. T. W. I. (O. B. S.), pumping is carried out not by a pump but by bullock power (Persian wheel).

Well No. 5 is a S. T. W. I. located just outside the area. It was drilled in 1967 in order to meet the shortage of drinking water caused by the heavy drought in 1966/1967 and was used for two years for supplying drinking water under the control of P. H. E. D. At present, the well is owned by L. I. D. but seems to be hardly utilized. It is estimated that about 0.064 m^3/sec of water can be pumped up from this well within 4 m of drawdown. If this well is put in full operation, therefore, it will be possible to supply irrigation water to one-third of the sub-centre area.

As for the geological condition at P. T. W. I. (No. 3), it is known that a coarse sand layer lies between the depths of 11 - 14 m and 40 - 48 m below the ground surface. According to the electric detection conducted on one sample taken at this spot, specific resistance above and below the depth of 60 m is 10 - 18   - m and 4   m respectively. It can be estimated from this fact that the lower part is composed chiefly of clayey soil. At S. T. W. I. (No. 5) which has a depth of 106 m, however, 5,340 m^3/day of water can be pumped up with a draw down of 3.46 m, though this is an estimated value not confirmed by actual measurement. The specific yield of this well therefore turns out to be a fairly large value of 1,540 m^2/day. From this estimate, it can be reasoned that the deeper part showing a lower specific resistance embodies artesian groundwater veins with a large flowing capacity.

Fig. 8-5 LOCATION MAP OF SURVEY SPOT
(GARHANI SUB-CENTRE)

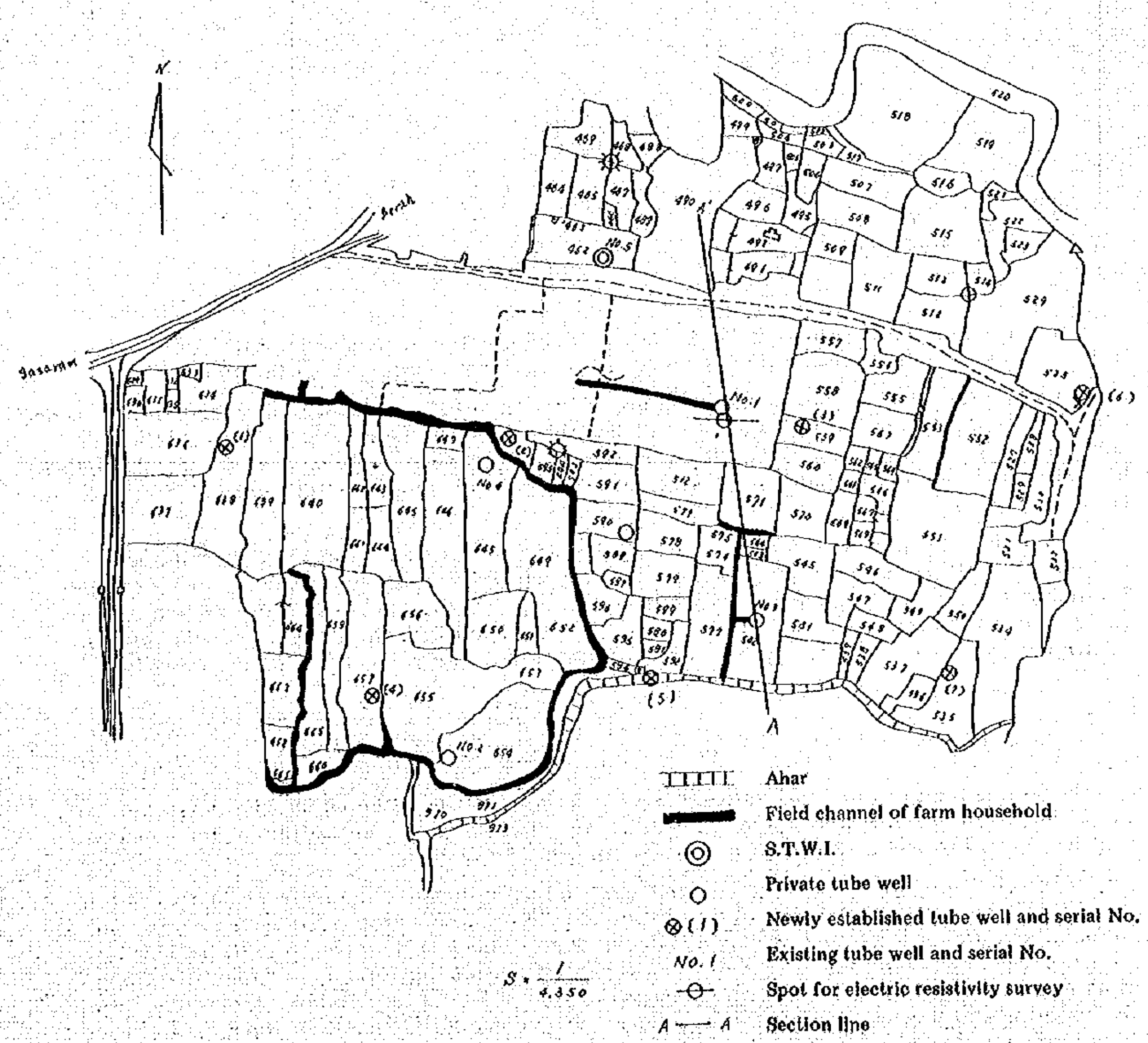
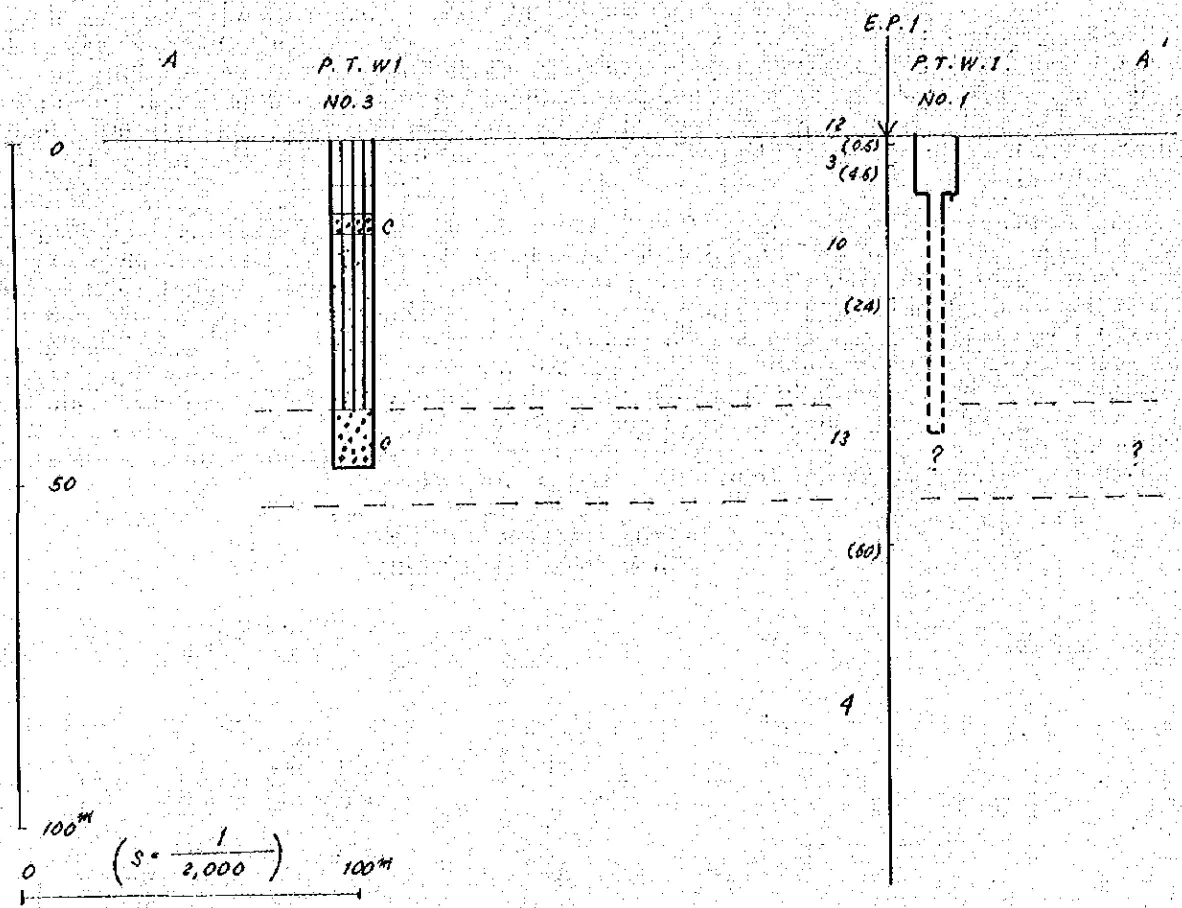


Fig. 8-6 GARHANI SUB-CENTRE



Groundwater temperature is 26.5 - 27.7 °C and electric conductivity 560 - 643 U/cm. It can therefore be said that water is taken from the same aquifer at all the wells.

The mission was informed that pumping operation at S.T.W.I. (No. 5) causes interference with P.T.W.T. located at the periphery of the area. This is considered ascribable to the pumping up of water from the 40 - 48 m deep aquifer. Though pumping test was conducted at this well in order to clear up the cause of interference, no accurate data were obtained due to power stoppage.

It was noted that water is pumped up from small rivers flowing in the adjacent area by means of 10 HP pumps. For future irrigation improvement, however, the mission considers it advisable to draw up a groundwater development plan rather than to resort to river water irrigation isnce it calls for negotiations and arrangements with the irrigation association, confirmation of annual availability of flowing water, and early construction of irrigation facilities.

8.5 Ekauna (No. 5)

Establishment of this sub-centre was necessitated because the nearby Kasap Sub-centre is no longer able to continue its activities. It is planned that the activities of this sub-centre will be started in the 1972 Kharif season in an area of 100 acres.

The sub-centre area is near the canal tail end but suffers water shorage just as in other areas. There are only two P.T.W.I.s which are 30 m in depth and 2.5" in diameter. In mapping out a plan for future water resources development in the area, it will be necessary to make a comparative study on the groundwater utilization and surface water utilization. Boring logs in the adjzcent farmland area are shown in Fig. 8-8. Judging from the aquifer distribution and the location of the sub-centre, it is considered possible to obtain a fairly large amount of groundwater in the area.

Fig. 8-7 RECORDS ON PUMPING TEST

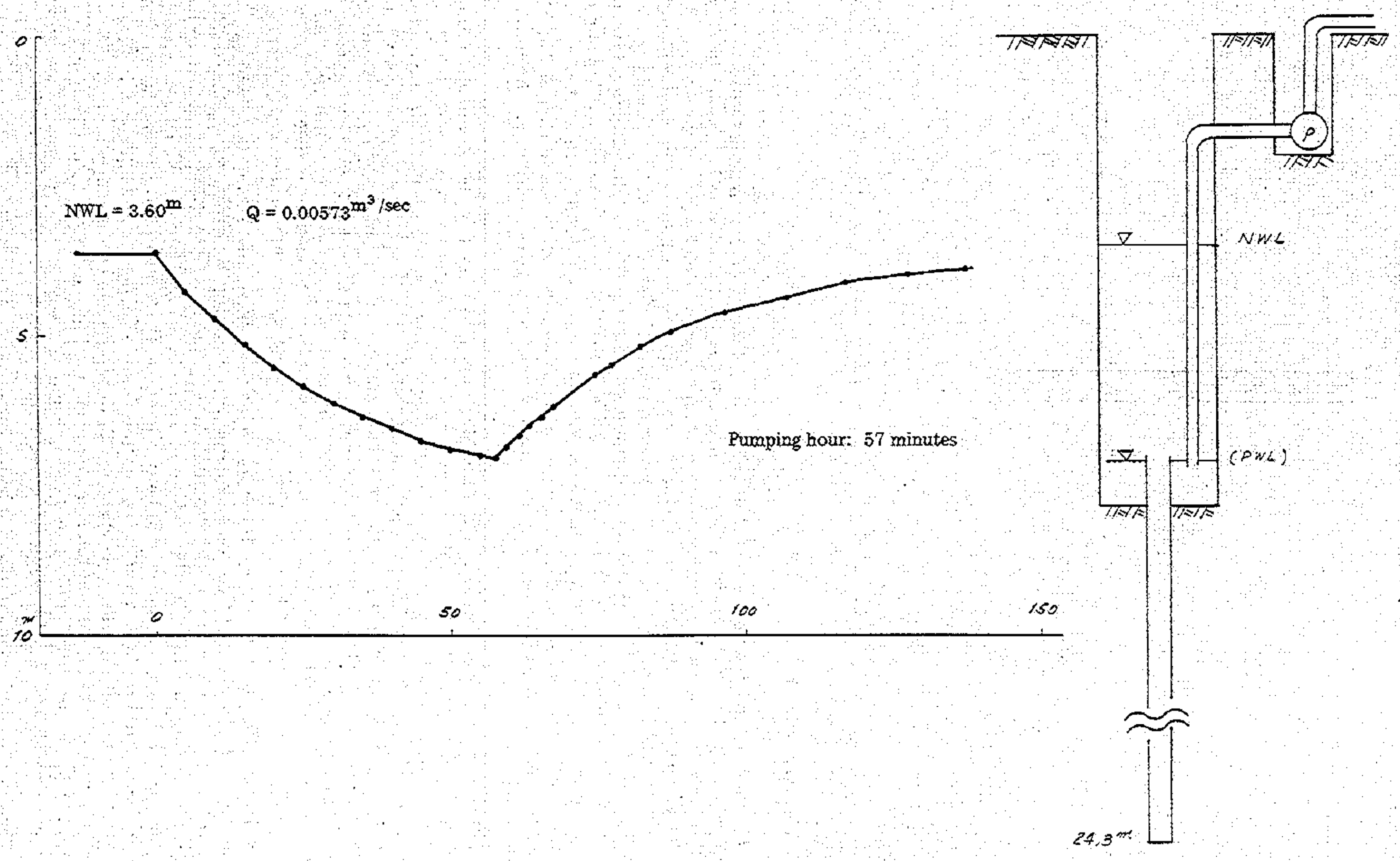
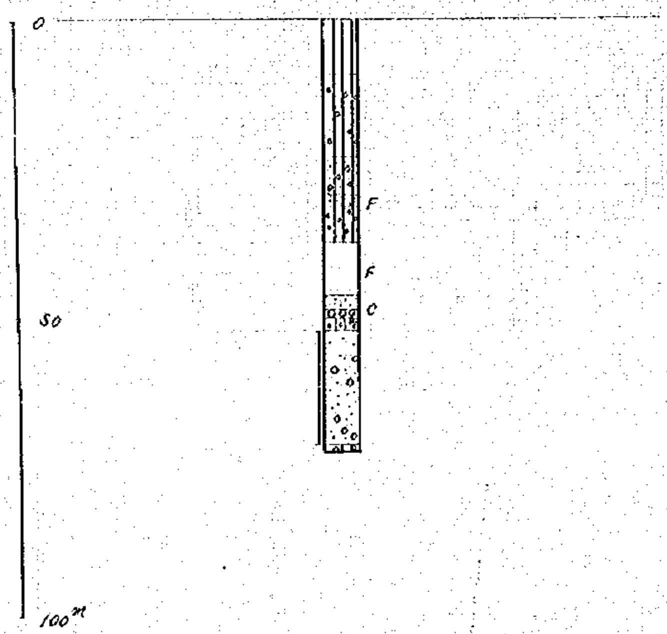


Fig. 8-8 EKAUNA SUB-CENTRE



8.6 Kulharia (No. 6)

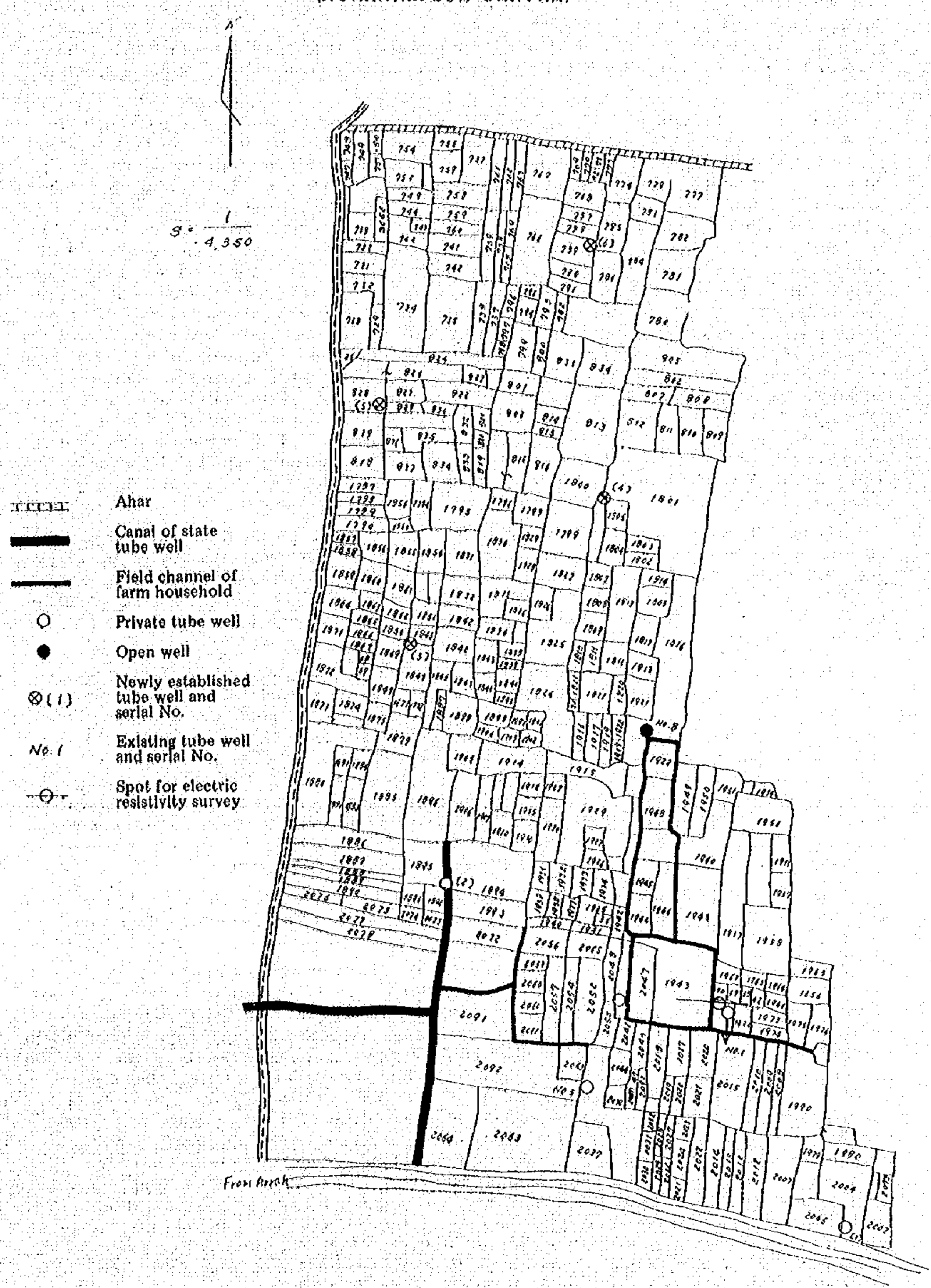
This sub-centre was established in 1969. Its 50 acrea area is planned to be expanded to 100 acres after the 1962 Kharif season. Since no canals are found in or around the sub-centre, the area's water sources are rain water, groundwater and flood water of the Ganga. Quite naturally, however, groundwater is the only water source available in the area for cultivation of Rabi crops and summer crops. There are installed three P.T.W.I.s ranging from 54 to 76 m in depth and 3 to 4" in diameter and equipped with a 5 HP centrifugal pump (See Figs. 8-9 and 8-10). Amount of water pumped is 0.007 - 0.015 lit/sec, and the daily pump operation hours is about 3 hours. Benefited area per tube well is said to be 10 - 12 acres in case of Rabi crops, 2 - 5 acres in case of summer crops and 10 - 20 acres in case of Kharif crops (Benefited acreage for cultivation of respective crops is approximately the same in other sub-centre areas).

In case the tube well owner holds a farmland area smaller than the command area, he supplies surplus water to the neighbouring farmers at a charge of 40 paisa/KWH (50 paisa in Katar Sub-centre area). This water charge is determined on the basis of the current electric rate of 20 paisa/KWH. To be more precise, it is set at twice the prevailing electric rate to cover the depreciation expense of the well and pump as well as miscellaneous expenses. Thus, the charge is based on the electric rate rather than the amount of water supplied. Accordingly, in case of Well No. 3 which consumes 1 KWH of power to pump up 15 m^3 of water, surplus water is distributed at a charge of 2.7 paisa/m^3. In case of Well No. 8, 1 KWH of power is required to pump 21 m^3 of water, so that the water charge is set at 1.9 paisa/m^3.

S.T.W.I. No. 1 (L.I.D. No. 10) is located about 200 m apart from the western boudary of the area. Terminal canal routes connected with this S.T.W.I. are shown in Fig. 8-9. This well has a depth of 69 m and a diameter of 6", and is equipped with a 12.5 - 15 HP submersible pump by which 0.048 m^3/sec of water is pumped up. Standard amount of water obtained from this well is reported to be 35,000 G.P.H. (3,800 m^3/day) which can cover an area of 100 acres for Rabi crops, 75 acres for summer crops and 125 acres for Kharif crops. Despite of the prevailing water shortage in the area, farmers' application for water supply from this well is rather limited for reasons described in Paragraph 7.3, Chapter VII. The well is not therefore utilized to capacity at present. The water charge was raised to about twice the rate shown in Table 4-16 as from February 1972.

The area is not irrigated by canal water because it is in Flooded Area and for this reason, both S.T.W.I.s and P.T.W.I.s are distributed in substantially large numbers. It is known that there are at least four S.T.W.I.s in the circular area extending within a radius of 1,400 m

Fig. 8-9 LOCATION MAP OF SURVEY SPOT
(KULHARIA SUB-CENTRE)



from Well No. 1. (See Table 8-2 and Fig. 8-10).

These S. T. W. I. s are approximately 76 - 83 m in depth and 8" in diameter, and are equipped with a centrifugal, bore hole or submersible water pump all having 12. - 15 HP power for pumping up 0. 0257 - 0. 0399 m^3/sec of water. Drawdown at all the wells is as mall as 2 - 3 m, so that specific yield reaches a relatively large value of 1, 200 - 2, 300 m^2/ day.

Both S. T. W. I. s and P. T. W. I. (No. 5) show a nearly constant temperature range of 27. 4 - 27. 7 °C and a relatively low conductivity of 43. 5 - 54. 2 μ. In case of P. O. W. s and P. T. W. T. s excluding Well No. 5, on the other hand, temperature is lower, ranging from 20. 6 to 24. 3 °C and average value of electric conductivity is above 500 μ. This conspicuous temperature difference between deep-seated groundwater and shallow groundwater is a common phenomenon in all sub-centre areas with few exceptions. Groundwater level of P. O. W. s can be readily observed and ranges from 4. 5 to 5. 7 m below the ground surface (Well No. 6 shows a smaller value of 2. 2 m). In case of P. T. W. I. s, water level of the upper open well portion can be observed with ease and shows a value of 1. 68 - 2. 2. These P. T. W. I. s are connected with the pump suction pipe, so that their open well portion is separated from the deep-seated groundwater as exemplified by Well No. 7 whose open well portion shows no water level fluctuation at time of pumping operation. Pumping water level of this well could not therefore be observed. All P. T. W. I. s have a 5 HP centrifugal pump installed in an underground pump house 2 to 2. 5 m below the ground surface. Observation of natural water level of S. T. W. I. s was possible only at Well Nos. 1 and 2, and pumping water level could be observed only at Well No. 12. The drilling record indicates that the natural groundwater level ranges from 4 to 5. 6 m below the ground surface at the end of April and drawdown from 2 to 3 m, so that the pumping water level can be calculated to be 6 - 8 m. This is why the pump house of S. T. W. I. s and P. T. W. I. s equipped with a centrifugal pump is built underground.

Boring ledgers of Well Nos. 1 and 10 (S. T. W. I. 10 and 17) show the seasonal fluctuation of groundwater level, though it is not known whether the values presented were obtained by actual measurement. The ledgers indicate that the water level at these two wells is 4. 8 - 5. 4 (16 - 18') in winter, 6 m (20') in summer and 3. 4 - 4. 5 m (14 - 15') in monsoon season. Hence, the drawdown is the largest in summer when it registers a value 1. 5 - 1. 6 m larger than in the monsoon season.

Boring log and data of electric detection at the existing S. T. W. I. s and P. T. W. I. s are shown in Fig. 8-11. As seen in the figure, the surface layer reaching down to a depth of 10 to 15 m consists of clay and sandy clay, which is underlain by a sandy layer extending further downwards to a depth of about 80 m. Down to a depth of 50 - 60 m, this sandy layer is composed of fine sand, with coarse sand grains prevailing in its lower part. Clayer layers confirmed by the survey are limited to the 40 - 45 deep layer at Well No. 11 and the one lying below the depth of 80 m at Well No. 10. It is possible however that other aquicludes will be found by electric detection. Considering the above-mentioned differences in well depth, groundwater temperature and electric conductivity, it is likely that the aquifer in this area is divided into two at a depth of about 50 - 60 m below the ground surface.

Data of electric detection (conducted at three points) indicate that the specific resistance is as low as 30 - m in the lower layer exceeding 80 - 110 m in depth below the ground surface.

Sand layers form good aquifers. However, since sand particles intrude into the tube together with groundwater, water is usually taken from layers ranging from medium to coasr in grain size. The slot number of strainer is determined by the grain size distribution of sand layer. M. I. D. adopts 40 per cent of the size obtained from the grain size accumulation curve in determining the slot number (40 - 50 per cent is applied in Japan). Figs. 8-12 shows the grain size accumulation curves obtained from the existing data as well as those prepared by M. I. D. As seen in the figure, the curves of S. T. W. I. 10 (No. 10) were prepared from four samples, of which Sample 4 may be considered gravel rather than sand, whereas Samples 1, 3 and 4 correspond not to medium but to granule - gravel in grain size. At P. T. W. I. (No. 13) which was put to an analysis during the survey, two kinds of materials were collected, i. e., coarse sand (Sample A) and granule (Sample B). The mission noted that the terms used in the above analytical results of M. I. D. and the boring log are not unified. It is hoped that efforts will be directed towards standardizing the terms. It is also to be pointed out that the grain size analysis is conducted within a very limited scope. Permeability coefficient at a water temperature of 27 °C as calculated by the application of Hazen formula using the uniformity coefficient and effective grain size obtainable from the grain size accumulation curves is

Fig. 8-10 DISTRIBUTION MAP OF WELL
KULHARIA SUB-CENTRE
(KOILWAR BLOCK)

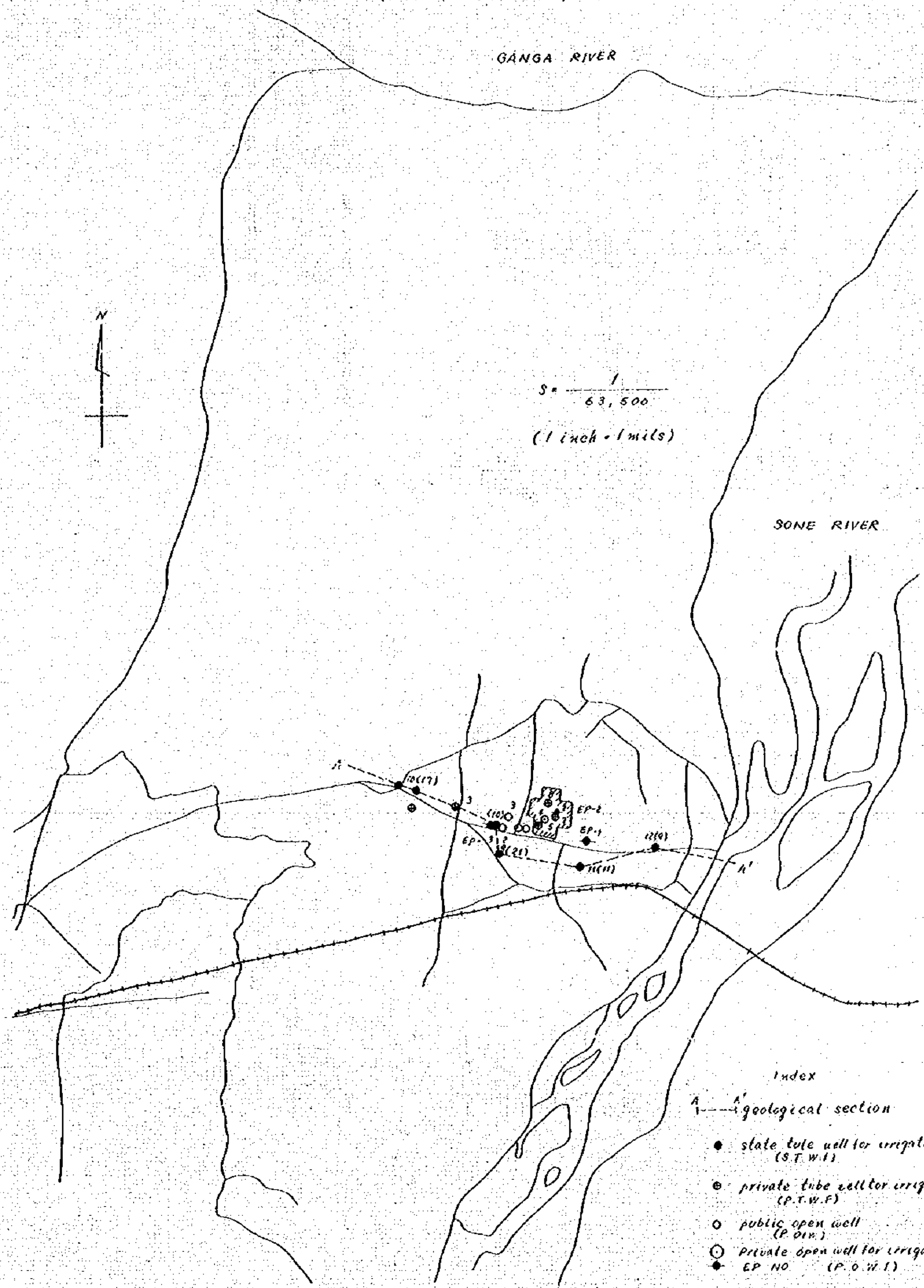
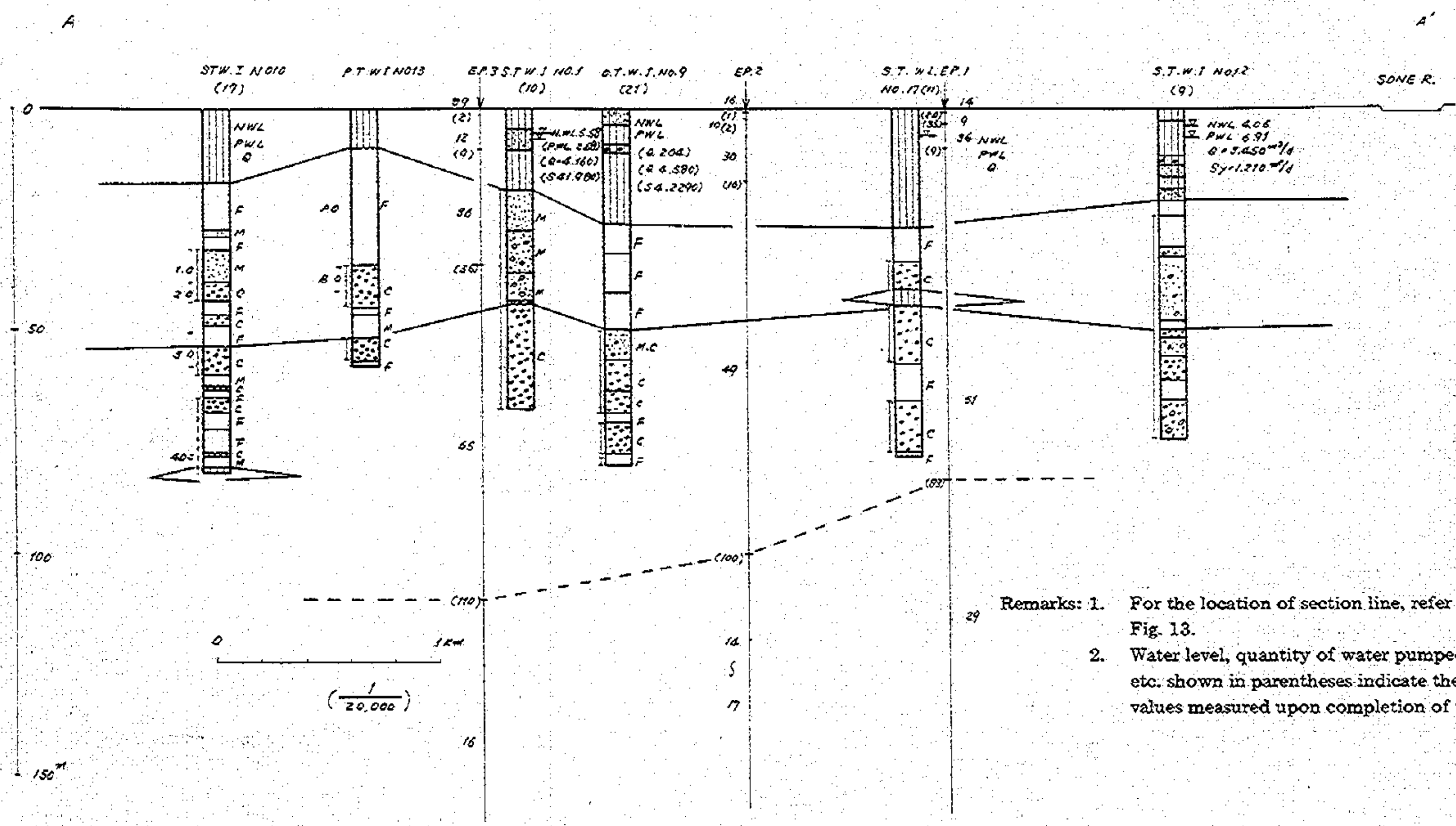


Fig. 8-11 KULHARIA SUB-CENTRE

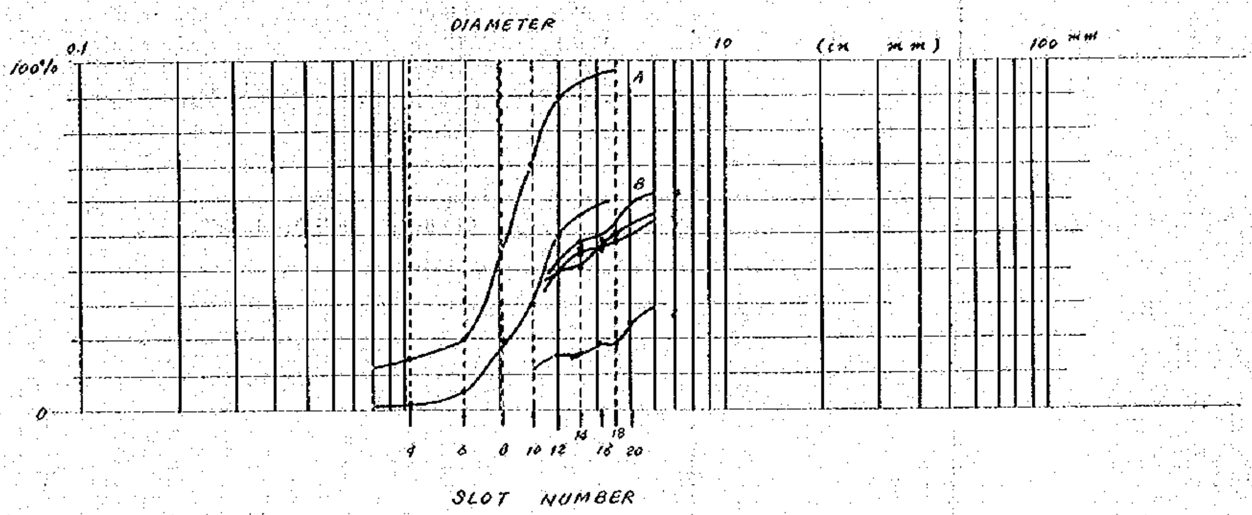


Remarks: 1. For the location of section line, refer to Fig. 13.

2. Water level, quantity of water pumped, etc. shown in parentheses indicate the values measured upon completion of wells.

$5 \times 10^{-2} \sim 6 \times 10^{-1}$ cm/sec in Sample A and $2 \times 10^{-1} \sim 5 \times 10^{0}$ cm/sec in Sample B. This suggests that both samples have a substantially high permeability.

Fig. 8-12 ACCUMULATION CURVE (KOILWAR BLOCK)

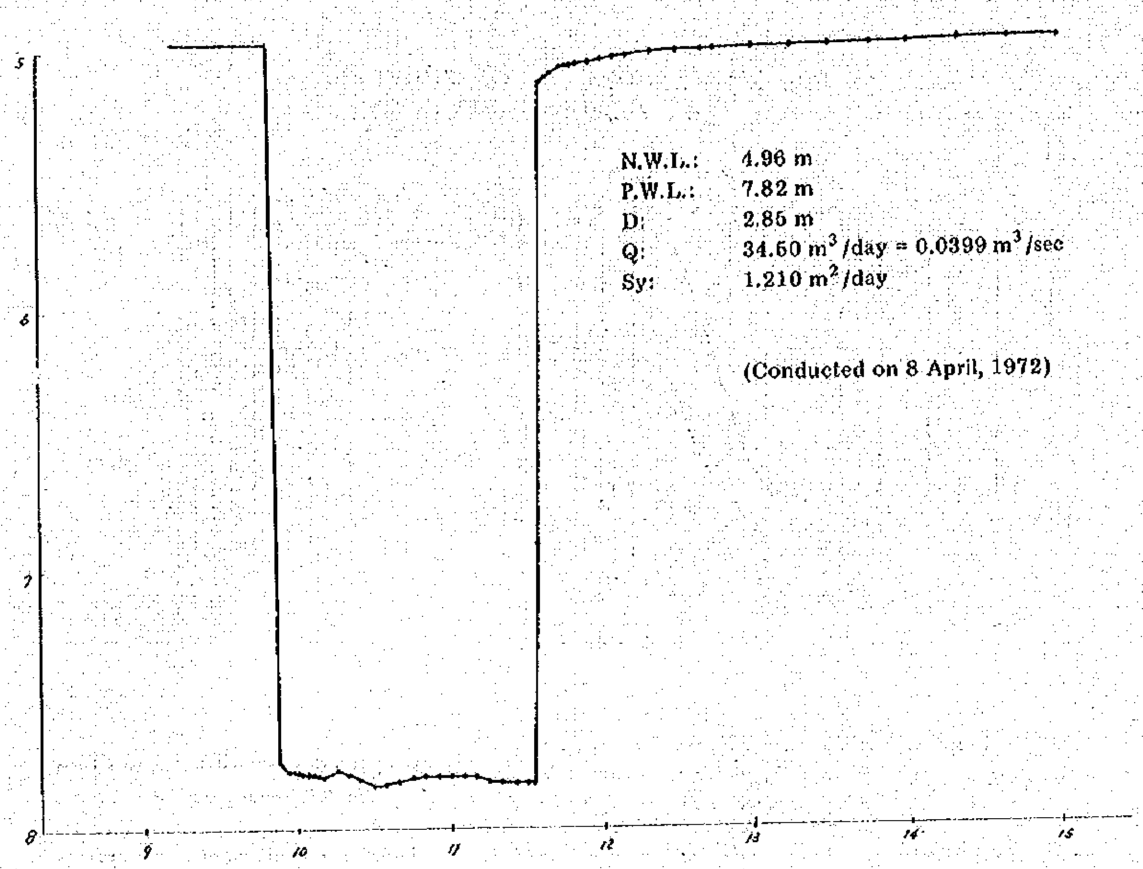


Sample	A.	P.T.W.I. No8	28'~118'	(8.4 ~ 35.4 m)	Analyzed during analised at this time
"	B.	P.T.W.I. "	118'~136'	(35.4 ~ 40.8 m)	
"	1.	S.T.W.I. No.10	106'~130'	(31.8 ~ 39.0 m)	Existing data suruey period.
"	2.	"	130'~145'	(39.0 ~ 43.5 m)	
"	3.	"	179'~197'	(50.7 ~ 58.1 m)	
"	4.	"	258'~260'	(77.4 ~ 78.0 m)	

Uniformity coefficient .... approx. 4

-do- .... approx. 24

Fig. 8-13 RECORDS OF PUMPING TEST



The only S. T. W. I. whose pumping water lwvel can be measured is Well No. 12 (9). Fig. 8-13 shows the data of pumping test conducted at this well. Due to service interruption, however, water could be pumped only for two hours, and further, since there could be found no observation wells, recovery formula was applied for tentative claculation of the permeability coefficient which turned out to be 3×10^{-1} cm/sec. This is smaller than the value obtained from the grain size accumulation curve, but indicates that the tube well site is permeable all the same.

Hydraulic data so far made public are shown in Reference Data 4 (Refer also to Bibliography 3). Since all those data are based on the observation conducted along the Ganga more than 90 km far from this area, they were not used in the analysis. In Shahabad district, hydrulic coefficients have been obtained from pumping tests only on very few occasions. Efforts should therefore be made for collecting a good deal of accurate hydraulic data in the coming years.

Chapter IX Preliminary Design of Tube Well

9.1 Introduction

The preliminary design was prepared only for Kulharia, Garhani and Katar Sub-centres. The mission wishes to note here that due to the short survey period, the subject area had to be limited to these three sub-centre areas where the farmers evinced strong enthusiasm for understanding, abosorbing and applying advanced techniques for practical purposes.

As mentioned already, pumping water level could not be observed at most of the existing tube wells in the three sub-centres and surrounding areas, nor was it possible to find any observation wells. This made impossible for the mission to conduct a complete pumping test at any well or to obtain hydraulic coefficients such as pumping water level and percorlation coefficient as well as storage coefficient which are indispensable for working out a water source development plan on the basis of theoretical speculation. For this reason, the preliminary design presented in this chapter involves errors which should be corrected from time to time in future when new data are obtained by drilling work.

The preliminary design was prepared by referring to the pumping condition at the existing wells which is shown in Table 9-1. As is clear from this table, small type P. T. W. I. s have a depth of 30 - 60 m and a diameter of 3 - 4" and are equipped with a 5 HP centrifugal pum pump by which 0.009 - 0.012 m^3/sec of water is pumped up. The tube wells in Garhani area, however, are smaller in both depth and flowing capacity so that they are not capable of continuous pumping operation.

On the other hand, S. T. W. I. s range from 76 to 143 m in depth and 6 to 8" in diameter, and are equipped with a 12.5 - 15 HP bore hole pump by which 0.037 - 0.064 m^3/sec of water is pumped up. Some of these wells are provided with a submersible pumps, though limited in number. (The upper part of S. T. W. I. s is of the housing structure which has a diameter of 12 - 15")

9.2 Study on Various Factors of Tube Well Design

9.2.1 Depth of Tube Well

In order to determine the depth of proposed tube wells, boring logs of existing tube wells were collected and electric detection was carried out.

In Kulharia area, Well No. 1 has the largest depth of 83 m as shown in Fig. 8-11. In the vicinity of this well, the upper claycy layer stretching between depths of 15 and 25 m below the ground surface overlies the sandy layer composed of fine sand in the upper part. In many cases, brass strainers with a horizontal slot are installed in the medium to coarse sand layers. Strainers with a vertical slot cut in the stee tube are also used. Record of electric detection indicates that layers lying below a depth of 100 m show low resistance values. Therefore, the design depth is set at 100 m in order to minimize interference from the existing wells.

In Garnam area and Katar area, low resistance values are observed in layers below a depth of 60 m and 75 m respectively. According to the boring logs shown in Tables 8-4 and 8-6, however, predominent aquifers can be observed in such low resistance layers. Accordingly, the design depth is set at 100 m, but this value is not to be adopted uniformly in the actual drilling work. Rather, shallower and deeper wells having an average depth of say, 80 m and 120 m respectively, should be arranged alternately. Further, strainers of adjoining wells should not be installed at a same depth.

9.2.2 Tube Well Structure, Pump and Power Equipment

Fig. 9-1 shows the representative tube well structures and their operation condition, characteristics, construction cost in India, etc. In case of Types 1 to 3 which will employ a centrifugal pump, it is absolutely necessary that the suction head is smaller than 7 - 8 m, so that the pump must be installed underground or in the well. Types 1 and 2 differ from each other in that the latter is belt-driven by power equipment set up on the ground surface an and its tube, which extends beneath the pump house, is two staged. In case of Type 2, the centrifugal pump can be replaced by a bore h91e pump if the annual fluctuation of pumping water level and groundwater level is unknown or the groundwater is liable to drop due to intereference. Conversion to Type 2 is therefore considered recommendable for sub-centres

Table 9-1 PUMPING CONDITION OF GROUNDWATER IN PRELIMINARY DESIGN AREA

Centre	Depth	Diameter	Amount of water pumped	Average of smount of water pumped	HP of Pump	Drawdown
	(m)		(m^3/sec)	(m^3/sec)		(m)
<u>Kulharia</u>						
P. T. W No. 5, No. 7 and No. 8	54 76	3" 4" 6"	0.0067 0.0152	0.012	5	Unknown
S. T. W No. 1, No. 9, No. 10, No. 11 and No. 12	76 83	6" 12" 15"	0.0257 0.0483	0.037	12.5 15	2.94 (Only No. 12)
<u>Carham</u>						
P. T. W No. 1, No. 2 and No. 3	30 32 (drilling) 12 14 (tube)	3	0.0057 0.0112	Calculation is impossible due to continuous flowing	5	Unknown (2.5 +)
S. T. W (No. 5)	106	12	0.064 (estimated)	0.064	15	3.5 +
<u>Katar</u>						
P. T. W	52.5	4	0.0085 0.010	0.009	5	Unknown
S. T. W. (No. 2)	143	18	0.055 (estimated) 0.044 (when newly drilled)	0.044	22.5	1.6 +

where Type 1 structure alone is adopted. It may as well be added that the power equipment installed on the ground can be used for farming work such as threshing. Type 3 is suited only when the groundwater level is high, and can be hardly found because ofthe difficulty in selecting its site. Types 4, 5 and 6 are provided with a bore hole pump and can be grouped into two kinds, namely, the housing structure type (Types 4 and 6) and the other type (Type 5). The former two types allow for the installation of a large capacity pump and therefore promise to pump up a large amount of water, and in addition, their power equipment can be installed at an elevated place to avoid flood damage. Bore hole pumps are lower in efficiency than centrifugal pumps.

India embarked in the production of submersible pumps in recent years, but they cannot be utilized to capacity at present since their operation at the desired time is not guaranteed due to unstable power supply. In addition, these costly home-made pumps are liable to run into faulty operation due to frequent voltage drop and sand intrusion from the sandy aquifer. When power supply condition becomes stable, however, drilling work will be much facilitated by the use of improved of submersible pumps. (Use of Japanese-made pumps is commendable by reason of their stable quality)

Fig. 9-1 COMPARISON OF TUBE WELL TYPES

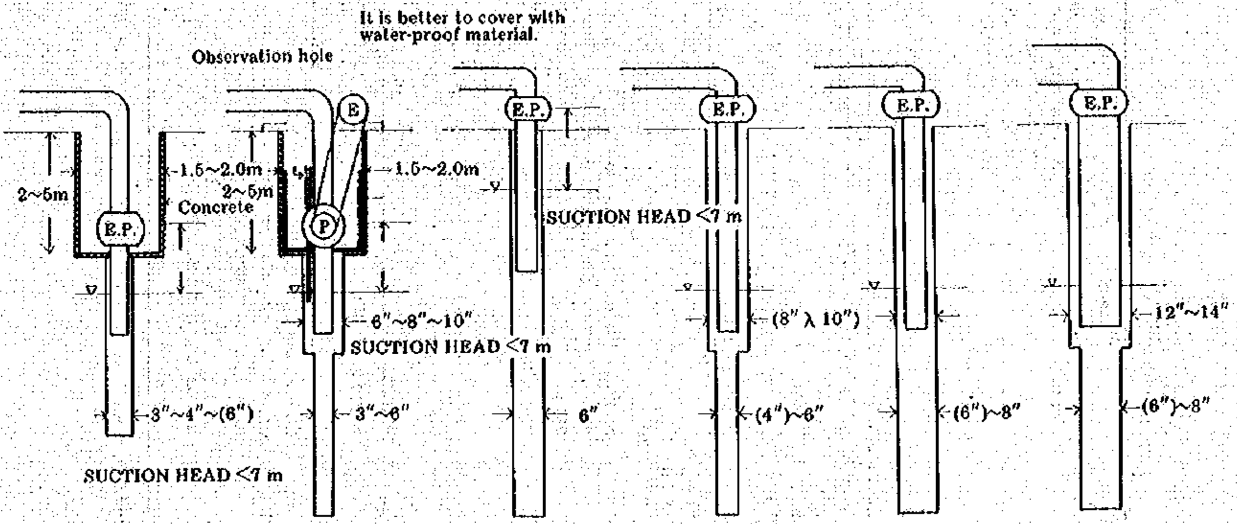


Fig. 9-1 (CONT'D)

Structure	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6
Operation Condition	Almost all private tube wells belong to this type which is equipped with a 5 HP centrifugal pump. (There are very few exceptional state tube wells which belong to this type)	Motor-driven and occasionally equipped with a 4" diameter tube. (EKAVNA)	Observed only in exceptional cases.	None.	None.	Almost all state tube wells belong to this type. 12.5 - 15 HP bore hole pups is used.
Characteristics	o When suction head is higher than 7 m, pumping operation becomes impossible. o Power machine of the pump must be removed when flood or groundwater intrusion threatens to occur. o Not suited in areas where the suction head is near the limit value or wells are drilled at small intervals. Drilling of this type of tube well calls for detailed hydrogeological survey.	o When suction head is more than 7 m, pumping operation becomes impossible. In such a case, however, a bore hole pumpe can be installed with ease. o Power equipment must be removed when flood or ground water intrusion is liable to take place.	o This type can be put in practical use only in areas where suction head is below 7 m, groundwater level is high and abundant flowing water is available. It is not considered to find such favourable areas though the operation and maintenance of this type can be done with ease. o This type is occasionally completed into Type 1 depending on the results of pumping test.	o Since water is pumped up by a bore hole pump, this type is free from the effect of water level flucutation. o Pump and power machine need not be removed even in Flooded Area.	o Same as the left. o Same as the left. o Data of pumping test can be analyzed with ease.	o Same as the left. o Same as the left. o Great amount of water is obtainable because large capacity power equipment and pump can be installed.
Construction Cost	(1) Rs. 10,000 - 12,000 (¥480,000 - 576,000)	(2) [About Rs.16,000] [About ¥768,000]	(3) Rs.16,000 (¥768,000)	(4) Rs.15,500 (¥744,000)	(5) Rs.20,000 (¥960,000)	(6) Rs. 24,000 - 32,000 (¥1,152,000-1,535,000)
Remarks	Drilling work is to be conducted for Type 2 operation, and converted to this type if the water level is found to be too high		Hardly acceptable due to the difficulty in finding the well site.		Large capacity pump cannot be inserted due to the small diameter. Hence, the unit pumping cost becomes high.	

Remarks: 1. Cost calculation is based on the commodity price in India (Refer to Reference Data 2).
2. Cost of Type 2 shown in brackets indicates the estimated cost and not the cumulative total cost requred.

Item Type	Type 1	Type 2	Type 4	Type 5	Type 6	Remarks: operated by commercial power
0. Drilling diameter	6"	8" (12" at the upper part)	12" (12" at the upper part)	12"	18"	
1. Well diameter	4"	10" at the upper part 6" at the lower part	10" at the upper part 6" at the lower part	8"	12"~14" at the upper part 8" at the lower part	4"
2. Construction cost of standard well	Rs. 11,000	Rs. 16,000	Rs. 15,500	Rs. 20,000	Rs. 24,000	Rs. 11,000
3. Kind, HP and diameter of suction pipe of pump	5 HP-centrifugal pump; $2\frac{1}{2}$"	10 HP-centrifugal pump; 4"	10 HP-centrifugal pump; (bore hole pump)	7.5 HP-turbine pump; (bore hole pump)	15 HP-turbine pump; (bore hole pump)	5 HP-centrifugal pump
4. Cost of pump	Rs. 385	Rs. 1,525	[Rs. 4,540]	[Rs. 3,830]	[Rs. 6,140]	Rs. 385 (5 HP-centrifugal pump)
5. Cost of diesel engine	Rs. 4,200	(Rs. 3,900)	(Rs. 8,900)	(Rs. 6,500)	(Rs. 14,400)	Rs. 1,200 (5 HP-motor)
6. Cost of generator	–	–	Rs. 22,100	Rs. 22,100	Rs. 28,750	–
7. Sum of costs of well, pump and power equipment (2 + 4 + 5 or 6)	Rs. 15,585	Rs. 25,425	Rs. 23,940	Rs. 30,330	Rs. 44,540	Rs. 12,585
8. Standard amount of water pumped	0.015 m³/sec	0.028 m³/sec	0.029 m³/sec	0.0136 m³/sec	0.0417 m³/sec	0.0144 m³/sec
9. Irrigation acreage (in case of 10 hours a day)	13.4 acres	25.0 acres	29.5 acres	12.1 acres	37.2 acres	13 acres
10. Construction cast of water source per 10 acres	Rs. 11,630	Rs. 10,170	Rs. 11,200	Rs. 25,100	Rs. 12,000	Rs. 9,680
11. Fuel cost for 10 hours of pumping	Rs. 8.1	Rs. 16.2	Rs. 16.2	Rs. 12.2	Rs. 24.3	Rs. 5.9
12. Fuel cost per 10 acres per 10 hours a day of pumping	Rs. 6.04	Rs. 6.48	Rs. 6.25	Rs. 10.08	Rs. 6.53	Rs. 4.54
13. Irrigation acreage (in case of 6 hours a day)	2.0 acres	15.0 acres	15.5 acres	7.3 acres	22.3 acres	7.7 acres
14. Construction cost of water source per 10 acres	Rs. 19,480	Rs. 16,950	Rs. 18,650	Rs. 41,600	Rs. 20,000	Rs. 16,340
15. Fuel cost for 6 hours of pumping	Rs. 4.9	Rs. 8.7	Rs. 9.7	Rs. 9.3	Rs. 14.6	Rs. 3.5
16. Fuel cost per 10 acres per of 6 hours a day of pumping	Rs. 6.04	Rs. 6.08	Rs. 6.25	Rs. 10.08	Rs. 6.53	Rs. 4.54

Remarks:
1. Bracketed figures indicate the pump cost obtained by multiplying the cost of pump and power equipment by 1/3.
2. Parenthesized unmbers are the estimated cost based on the costs in Japan.
3. It is said that 25 per cent of cost will be subsidized in case of diesel engine. However this subsidy was disregarded in calculsting the costs shown in this table.

Table 9-3 RECORDS ON NATURAL WATER LEVEL AND PUMPING TEST

Sub-center	No. of Well	Well Group	Fluctuation of Natural Water Level			Record of Pumping Test				Remarks
			Summer	Monsoon	Winter	Natural Water Level	Pumping Water Level	Drawdown	Amount of Water Pumped	
Kulharia	No. 1(10)	State tube well	–	–	–	–	–	7'(2.1m)	G.P.H. 38,000 (4,160m³/day)	Test period: End of Sept. 1947
"	No.10(17)	"	20'(6.1m)	11'(3.36m)	16'(4.88m)	–	–	–		Test period: Middle of Sept. 1962
"	No.11(11)	"	20'(6.1m)	15'(4.57m)	18'(5.49m)	–	–	–		Test period: Middle of No. 1947
"	No.12(9)	"	–	–	–	–	–		G.P.H. 42,000 (4,580m³/day)	Test period Middle of Nov. 1947

9.2.3 Daily Pump Operation Hours

At present, water is pumped up by motor for 2 to 3 hours from P.T.W.I.s. At one of S.T.W.I. attended by a full-time operator, the pump operation hours is 3 to 8 hours a day (See Fig. 7-2). This short pump operation hours is assignable to the unstable power supply and the small size of irrigation area which does not call for any long operation hours.

Efficiency of pump engines generally rises with the increase of daily operation hours. Juding from the present pumping condition and working hours, however, it does not seem justifiable to effect any drastic increase of daily operation hours under the present improvement plan. It may as well be proposed, however, to double or treble the current operation hours to 6 to 10 hours a day. As for new wells which will be operated jointly by a number of farmers, it is considered both reasonable and practicable to set the daily operation hours at 6 hours.

When farmers gain skill in the pump operation and become eager to cut down the operation and maintenance cost as well as depreciation expenses, then it will be possible to operate the pumps for longer hours (say, 10 hours a day) and supply surplus water for irrigation of the surrounding farmland areas.

9.2.4 Design Head

Natural water level measured by the mission was close the lowest water level because the survey was conducted in the drought season (April). Natural water level varies by the well structure (depth) and location and its minimum value is about 6 m (See Table 8-2). Existing geological logs indicate that the lowest value of 20' (6.1m) is recorded in summer and the highest of 11 - 15' (3.4 - 4.6 m) in monsoon season (See Table 9-3). Head of centrifugal and bore hole pumps was obtained on the basis of these values.

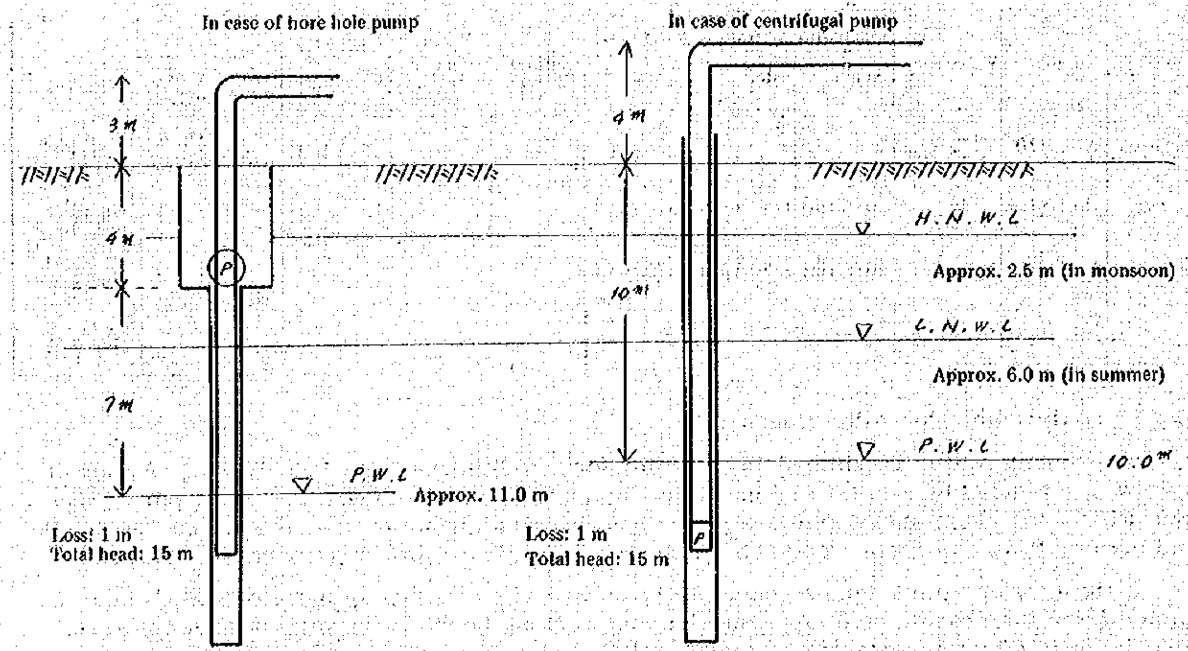
9.2.4.1 Centrigual Pump

If the lowest natural water level is 6 m and this level declines further by pumping operation, then it is necessary to built an underground pump house. If the pump house is built at a depth of 4 m with some margin provided for safety's sake, groundwater level will rise above the bed height of pump house in the monsoon season. The pump house should therefore be protected with watertight conterete walls. If, again, the highest suction head is 7 m, static discharge 3 m above the ground surface and friction loss head 1 m, the total head turns out to be 15 m.

9.2.4.2 Bore Hole Pump

As shown in Tables 8-2 and 9-1, 3,000 - 4,500 m^3/sec of water can be pumped up with a bore hole pump from tube wells having a diameter of 6 - 8" within 2 - 3 m of drawdown. Therefore, if the lowest water level is assumed at 6 m and drawdown at 4 m with some margin, the pumping water level comes out to be 10 m. If the friction loss is set at 1 m and static discharge head above the ground surface at 4 m for future piping planning since bore hole pumps promise to provide a large amount of water and cover a wide irrigation area, then the total head reaches 15 m. (In Japan bore hole pumps have given place to submersible pumps and are no longer included in the production line)

Fig. 9-2 HEAD DESIGN



9.2.5 Design Amount of Water Pumped

Horse power of the pump to be installed and the amount of water that can be pumped up can be calculated when the drilling diameter and total head are determined. A 5 - 10 HP centrifugal pump can be installed for Types 1 and 2 and a 7.5 - 15 HP turbine pump for Types 4, 5 and 6. Standard amount of water pumped is 0.015 m^3/sec in case of Type 1 and 0.0417 m^3/sec in case of Type 6. These figures were obtained by the tests conducted chiefly with Indian-made pumps. Type 3 is excluded from Table 9-2 because its application is not considered commendable.

Design amount of water that can be pumped up by the above-mentioned pumps is nearly equivalent to or slightly larger than that obtainable at the existing wells (See Tables 8-2 and 9-1). However, since the depth of the proposed wells and the diameter of some of them are larger than those of the existing wells, it can be expected that the amount of water will surpass the standard value given above.

9.2.6 Unit Duty of Water

Unit duty of water for crop cultivation varies by season and growing stage. The values calculated by Dr. H. Pandy are shown in Table 4-11. Peak duty of water, which ranges from 10 to 15 mm/day, occurs in the puddling period for Kharif and summer crops. Kharif season is blessed with much rainfall, but summer is not and demands that 10 mm/day of water be supplemented. Accordingly, water source development is studied on the basis of the unit duty of 10 mm which is equivalent to 404 m^3/day/10 acres or 0.0187 m3/sec by 6 hours of pumping operation a day.

9.2.7 Tube Well Irrigation Acreage

Tube well irrigation acreage can be obtained by dividing the design amount of water pumped by the unit duty of water (See Item 9.13, Table 9-2). If water is pumped up for 6 hours a day, a minimum of 8 acres (Type 1) and a maximum of 22.3 acres (Type 6) can be covered.

Type 1 is recommended to be excluded from the water source development plan because pumping operation is liable to become impossible in this type due to the increase of suction head.

Judging from the tube well irrigation acreage and the present operational holding of farmers, newly established wells will have to be used jointly by a number of farmers, and this will call for the creation of irrigation associations. Since no such cooperation organizations have been in existence in rural areas of India, it is expected that various problems will be encounstered in the course of their establishment and manangement. It is to be noted, however, that rearing of such cooperative organizations is one of the prime objectives of extension activities. It is also to be taken into consideration that each irrigation association should be so organized as will be composed of a limited number of farmers and cover a small area. This is one of the practical needs to be fulfilled for smooth operation of irrigation association.

9. 2. 8 Distribution of Wells

It is advisable that tube wells be so distributed as will not cause mutual interference or decline of water level. For this purpose, well distribution plan should be worked out after delineation the influenced circle by actual survey or calculation based on hydraulic coefficients. While such survey or calculation was not made during the present survey, well interval is established as follows under the bylaw of L. I. D. and M. I. D.

1) Tube wells with less than 4" diameter should be established at intervals of 1, 000' or more (300 m or more).
2) Tube well with more than 6" diameter should be established at intervals of 1, 500' or more (450 m or more).

This bylaw, however, provides only for the principle and it is known that there are many exceptions to this general rule. In addition, the bylaw is not applied to the case where a well is drilled by an individual with his own fund. The mission was not therefore able to ascertain on what basis the bylaw was enforced.

Distribution of tube wells should be planned not just by the interval, but account must be taken of the depth and amount of water pumped as well, and in certain cases, minor interference should be allowed if unavoidable.

All sub-centre areas must resort, at least for the present, to groundwater for supply of irrigation water (See Table 8-1). In each sub-centre area, therefore, benefit of drilling many small size wells (about 4' diameter) should be compared with that derivable from drilling a few large size wells (about 6" diameter). Table 9-4 shows the irrigation acreage, number of tube well required, etc. as calculated on the basis of 10 hours and 6 hours of daily pumping operation with Types 2 and 6 taken as respresenting small and large size well respectively. (Refer also to Paragraph 9. 2. 1. 1) As seen in this table, Plan A demands that the largest number of wells, i. e., 20, be drilled at intervals of 276 m, whereas Plan B calls for drilling of the least number, i. e., 9 wells, at intervals of 436 m. Under other plans, well interval averages about 350 m which is much smaller than is set by the above-mentioned bylaw.

If a certain fixed amount of water is to be pumped up within a limited area and no limit is set on the construction cost, then it would be most commendable to pump up water from many small wells because any trouble in groundwater source such as abnormal drawdown and ground settlement will affect not a part but the whole of the area. Hence, water source development and well distribution should be planned in an integrated manner after examination of various factors including the construction cost.

Introduced below is the comment on the well interval contained in Reference Data 4, though this comment is not based on the study of hydro-geological data.

The comment states that high yield tube wells should be installed at intervals of 0. 9 m and small tube wells with a diameter of 4" - 6" at intervals of 0. 2 km, and burther states that in the southern part of Shahabad district, 1. 2 km interval is required between state tube wells and 0. 4 km between smaller tube wells. In the area extending along the Ganga and the Sone, the comment states, wells can be installed at intervals of less than 0. 4 km. This means that smaller tube wells in the preliminary design area can be arranged at intervals of 0. 2 km or even smaller.

It goes without saying, however, that the well interval should be determined on the basis of reliable data.

9. 2. 9 Economic Comparison of Water Source Facilities

Estimated unit construction cost of water source facilities per 10 acres of irrigation area is shown in Table 9-2 (Items 10 and 14). This was obtained by dividing the total cost of tube wells, pumps and diesel engines (Item 6, Table 9-2) by the irrigation area (Items 9 and 13, Table 9-2). The calculation indicates that Type 2 is the cheapest and Type 5 incurs the largest cost. Type 5 is planned for pumping up water by a turbine pump, but since the well diameter (i.e., suction pipe diameter) is small, amount of water pumped will be too small relative to the high cost of tube well and engine. Economically, therefore, Type 2 is most preferable.

Cost of fuel (diesel oil) is almost the same with the exception of Type 5 (See Item 16, T Table 9-2). If daily pumping hours is maintained constant, therefore, Type 2 can be considered most advantageous and Types 4 and 6 may be proposed as alternatives.

Diesel oil costs about 1.3 times the current electric rate, but offers the great merit of making it possible for farmers to pump up water at any desired time. Further, not only the fuel cost but also the construction cost can be repaid without difficulty in case diesel oil is used.

Yields of high yielding varieties of paddy, wheat and other crops cultivated with sufficient supply of irrigation water and application of fertilizers are described in Bibilography 5.

9.2.10 Water Distribution Method

Extesnion of intensive agriculture should essentially include farm consolidation work for infrastructural improvement. However, the current extenstion programme is planned to be completed by the end of March 1973. Further, farmers do not employ agricultural equipment worthy of the name by reason of abundant labour force and tend to shy away from the conversion and exchange of land involved in the farmland consolidation work. As pointed out by the experts stationed at Arrah Centre, what must be done at present for assuring spill-out effect from continued extension activities is to make farmers try and understand for themselves the possibility of year-round cultivation (three crops a year) in their respective fields.

For this reason, it is planned that water will be supplied by the existing field channels and temporary earth canals or for plot-to-plot irrigation during the current extension period ending in March 1975 without effecting any canal consolidation, though water sources for such water supply will of course be secured.

At the stage of preliminary design or construction work, however, introduction of pipeline irrigation will have to be studied as far as practicable as a water distribution method not entailing conversion and exchange of land. Since all sub-centres have approximately the same gradient, greater part of sub-centre areas will become irrigable by natural land settlement, but it is considered that water distribution by pipelines or other means will be required in certain limited parts.

9.2.11 Factors of Water Source Development Plan

In the foregoing pages, comparative study was made on a number of water source development plans and relevant basic data (See Table 9-2).

The mission holds the view that the final plan should be such that affords ample allowance for ensuring smooth pumping operation and has economic advantage as well. If comparative study is made from this viewpoint on the plans shown in Table 9-4, preference can be given to Plan A' (6 hours pumping a day by Type2) and Plan B (10 hours pumping a day by Type 6) over other plans as already stated in Paragraph 9.2.8. Table 9-5 shows the results of further comparative study of these two selected plans.

From the comparison made in Table 9-5, preference can be given to Plan A' over Plan B except in the construction cost and tube well intervals. Though economic advantange (cost) can never be left out of consideration because the present project aims primarily at agricultural extension activities, it does not have to be considered a binding factor as in ordinary private undertakings. As for the aforementioned bylaw of well interval, the mission considers that it is not based on a prudent study and should therefore be revised in the course of the calculation of groundwater balance. In this preliminary design, therefore, Plan A' is recommended as being most desirable and Plan B as the second best. Factors of Plan A' are summarized below. These factors apply to all preliminary design areas.

Table 9-4 WELL INTERVAL AND ESTIMATED COST BY WATER SOURCE

Water Source Plan	Commanding Area	Well Interval	Number of Newly Drilled Well	Estimated Construction Cost	Remarks
	(acres) (ha)	(m)	(No.)	(Rs)	(No.)
Plan A (Type 2; pumping 10 hours a day)	25.0 (10.0)	(350)	12	366,000	6" equivalent (Type 2; 12)
Plan A' (Type 2; pumping 6 hours a day)	15.0 (6.0)	(276)	20	609,000	6" equivalent (Type 2; 20)
Plan B (Type 6; pumping 10 hours a day)	37.2 (14.9)	(436)	9	408,000	6" equivalent (Type 6; 6) (Type 2; 3)
Plan B' (Type 6; pumping 6 hours a day)	22.3 (8.9)	(336)	14	701,000	6" equivalent (Type 6; 12) (Type 2; 2)

Remarks: Estimated construction cost is obtained by the following procedures.
1. Unit cost shown in Table 10 is multiplied by respective numbers of tube wells.
2. 20 per cent of the cost thers obtained is added as overhead costs.

(1)	Average depth:		100 m (330')
(2)	Well structure:		Type 2 (refer to Fig. 9-1)
(3)	Drilling diameter:	0 - 4 m	1.5 - 2 m
		4 - 30 m	(8") - 10"
		30 - 100 m	6"
(4)	Well interval:		276 m
(5)	Type of pump:		centrifugal pump
(6)	Power:		10 HP diesel engine
(7)	Diameter of suction pipe:		4" - (6")
(8)	Diameter of outlet:		4" - (6")
(9)	Total head:		15 m
(10)	Amount of water pumped:		0.028 m^3/sec
(11)	Daily operation hours for pumping:		6 hours
(12)	Irrigation area:		15 acres (6 ha)
(13)	Water distribution method:		plot-to-plot irrigation by field channel; partly by pipe line

Table 9-5 PRIORITY COMPARISON BY WELL SIZE

	Item	Plan A' (Type 2; 6 hrs pumping/day)	Plan B (Type 6; 10 hrs pumping/day)	Preferable Plan	Remarks
Technical Aspect	Groundwater Level	Pumping water level declines generally.	Pumping water level drops largely near pumping wells.	A'	Consolidation settlement of clayey layer should be checked.
	Grounwater Trouble	Any trouble in groundwater source will be observed in the whole area.	Trouble in groundwater source will be observed only around pumping wells.	A'	
	Well Interval	Somewhat small (276 m)	Suitable (435 m)	B	Tube well interval should be quantitatively examined. Refer to Table ____
Economic Aspect	Unit Construction per Acre	As many as 20 tube wells are required due to 6 hours operation hours per day. This makes the construction cost rather high.	Since water will be pumped with large capacity pumps for 10 hours a day, number of wells can be limited to 9. This will make the construction cost relatively low.	A	Construction cost generally decreases with the increase of capacity and diameter of pump if engines, pumps and wells are all of the same type.
	Operation and Maintenance Cost	Fuel cost varies little, but operation and maintenance of pumps will demand much labour force and cost.	Fuel cost varies little, but operation and maintenance of pumps will demand much labour service and cost.	(B)	Labour cost is not an important factor because of abundant availability of labour force.
Management Aspect	Irrigation Association	Irrigation area per tube well is relatively small, so that irrigation association can be simple in organization well management can be done with ease.	Irrigation area per tube well is relatively large. Hence, so much the larger larger number of farm households should be covered and irrigation association will not be simple in organization. Further, well management will be difficult.	A'	Irrigation association can created and managed with ease if organized by a small number of members because farmers are not experienced in organized activities.
	Working Hours	Since water will be pumped up for 6 hours a day, working hours will be increase sharply.	Though water will be pumped up for 10 hours a day by joint management of well, working hours will sharply increase and management will be rather difficult.	A'	6 hours pumping operation is considered suitable in the transition stage.
	Distributary	Since the command area per tube well is small, water can be distributed even by small open channels or temporary canals, and there will be little idle land.	Since the command area per tube well is large, distributaries should be consolidated, so that idle land becomes large in area.	A'	Laying of underground pipelines will not cause any idle land, but further study should be made due to the difficulty in the pipeline irrigation.
	Countermeasure against Failure	Water can be readily supplied from nearby wells in the event of failure of pump, engine etc.	Water can be hardly supplied from nearby wells in case of failure of pump, engine, etc.		

Chapter X Preliminary Design

Study on the preliminary design is made in the following pages on the basis of the factors presented in the preceding chapter.

10. 1 Kulharia

In Kulharia Sub-centre, there are 3 P. T. W. I. s as shown in Fig. 8-9 and Table 8-2. Outside the western boundary of the area is S. T. W. I. No. 1 whose concrete-lined canals are constructed within this sub-centre area. If water source development plan is mapped out for utilizing the three P. T. W. I. s just as at present, namely, by pumping water from them for 3 hours a day, 9. 6 acres of area can be irrigated.

S. T. W. I. No. 1 (10) cannot serve as a stable water source in this area due to unstable power supply. Therefore, an area of 90. 4 acres must be covered by new tubw wells (See Table 10-1). Since one standard tube well can command an area of 15 acres (See Item 13, Table 9-2), 6 new tube wells will have be drilled. 15 acre area is equivalent to a circular area having a radius of 138 m, and this means that the new tube wells should be arranged at intervals of 276 m as shown in Table 9-4. This well arrangement is plotted on the map shown in Fig. 10-1.

The above tube well distribution is basically planned to satisfy the following requirements.

1) Intervals should be set at 276 m between new tube wells as well as between new and existing wells.

2) Distribution of tube wells at higher places should be made easy.

3) Maximum utilization of existing wells should be made possible.

10. 2 Garhani

There are 4 P. T. W. I. s in this sub-centre area as shown in Fig. 8-5 and Table 9-1. Since the size (depth) of these wells is small, amount of flowing water is so limited that water cannot be pumped up continuously. If these wells are to be put in use continuously in future, it will be impossible to drill new wells even at intervals of 276 m. For this reason, these existing wells will be abandoned in order to drill new ones.

As will be clear from Table 10-1 and Fig. 10-2, 7 tube wells are required per 100 acres in this area where field channels and Ahar are available for water distribution.

Existing Well No. 5 is a S. T. W. I. Though this well is located in the northern part of the area, it is practically in no use at present and is not likely to be put in use in future due to the absence of distributaries and unstable power supply. All the water source in the area will therefore be provided to new tube wells, disregarding Well No. 5.

Fig. 10-1 LOCATION PLAN OF NEW TUBEWCLL
(Kulhania Sub-Center)

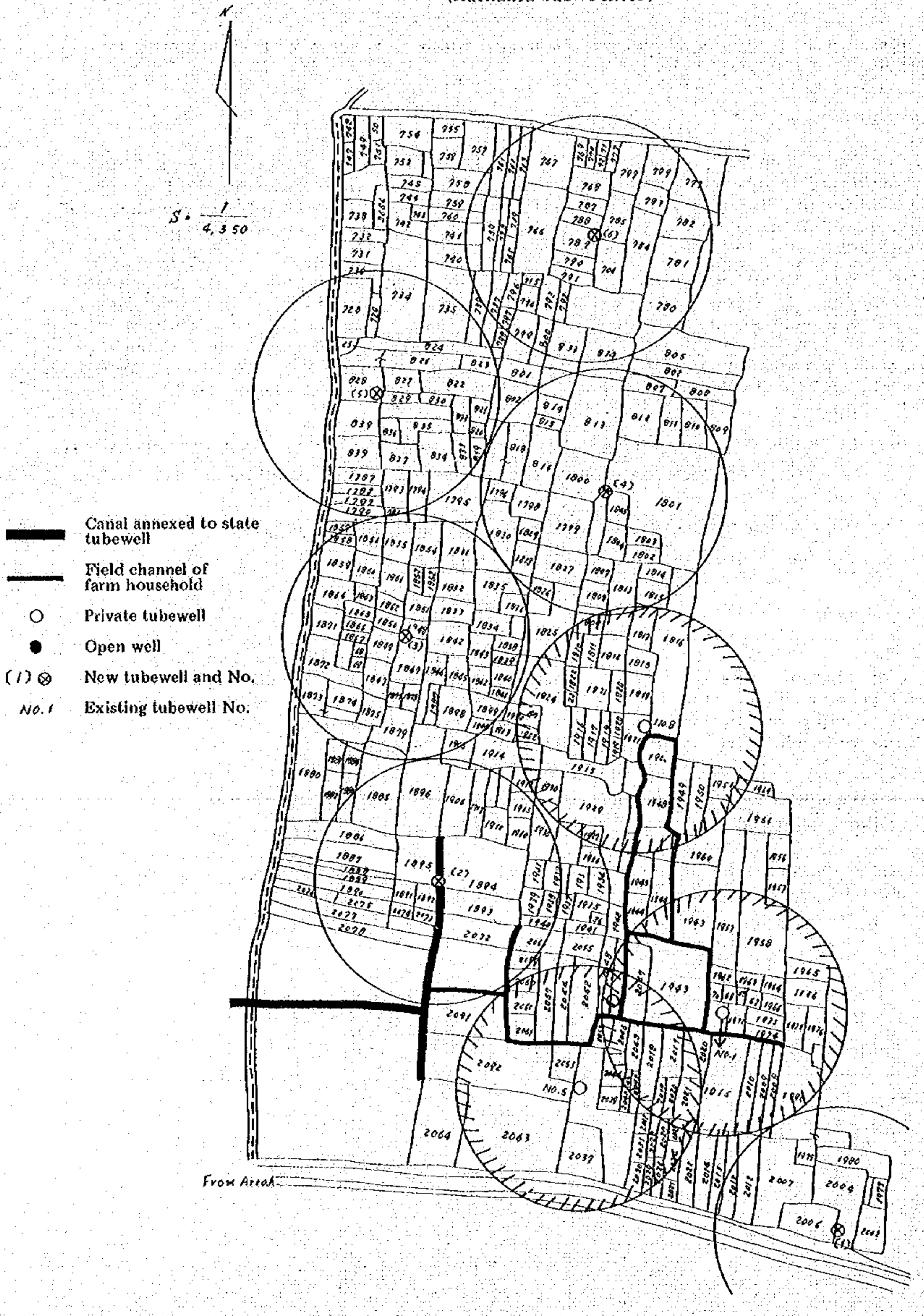


Table 10-1 SUMMARY OF WATER SOURCE DEVELOPMENT PLAN

Sub-centre	Acreage	Irrigation acreage by Existing Private Tube Wells (pumping: 3 hours a day)		Irrigation Acreage by New Tube Wells	Numbers of New Tube Wells (Type 2) Required		Estimated Construction Cost
	(acres)	(acres)	(No.)	(acres)		(No.)	(Rs.)
Kallaria	100	9.6	(3)	90.4	6.04	6	183,000
Garhani	100	Existing tube wells to be abandoned, and only new tube wells are to be utilized.		100.0	6.7	7	213,000
Kator	100	4.8	(2)	95.2	6.3	7	213,000
Observation wells in respective sub-centres					Observation well	3	43,000
Total	300	14.4	(5)	285.6		(23)	652,000
						20	609,000

Remarks: 1. Plan A: Type 2 _ _ _ in case of pumping for 6 hours a day
2. Bracketed figures indicate the numbers of tube wells and their construction cost including those of observation wells.

Fig. 10-2 LOCATION PLAN OF NEW TUBEWELL (GARHANI SUB-CENTER)

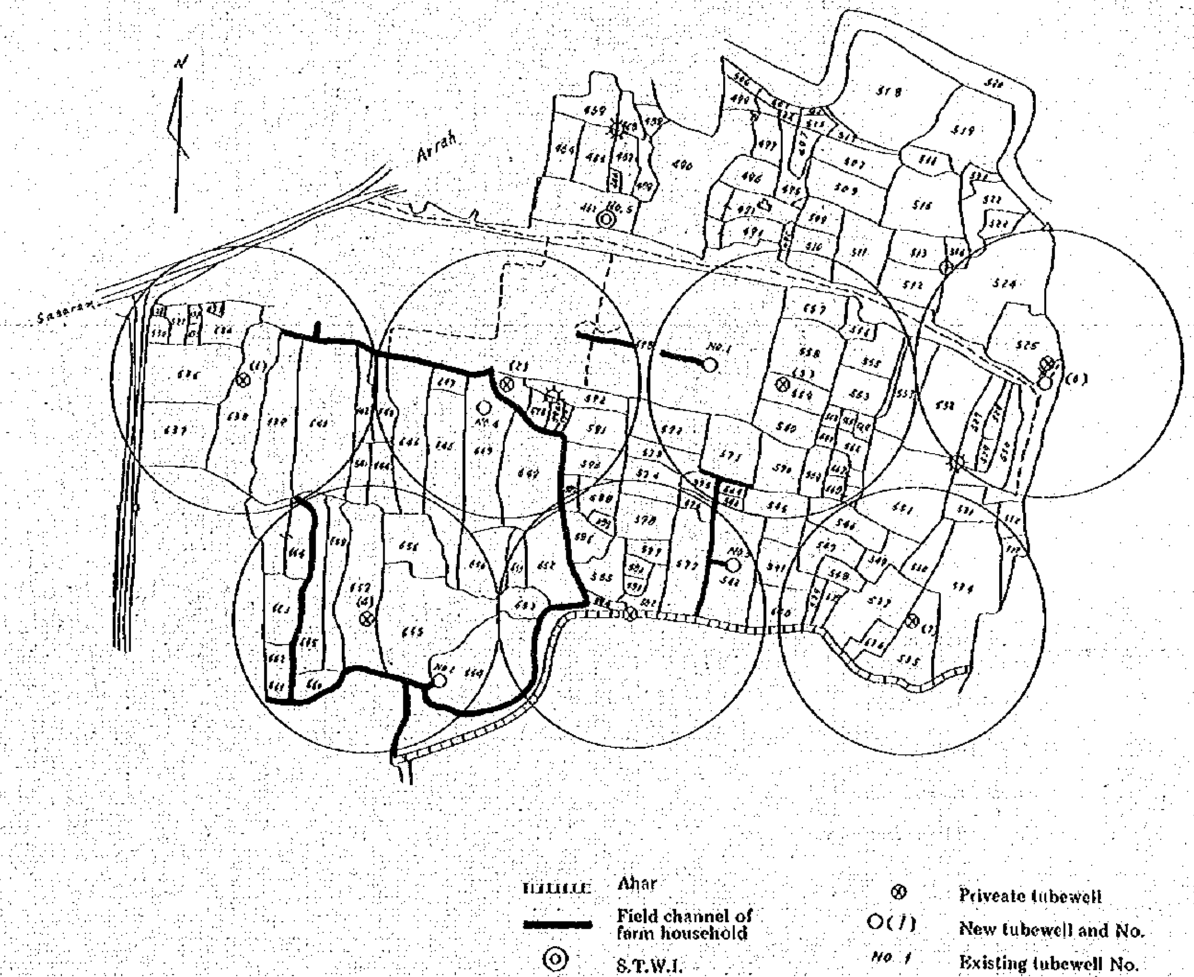
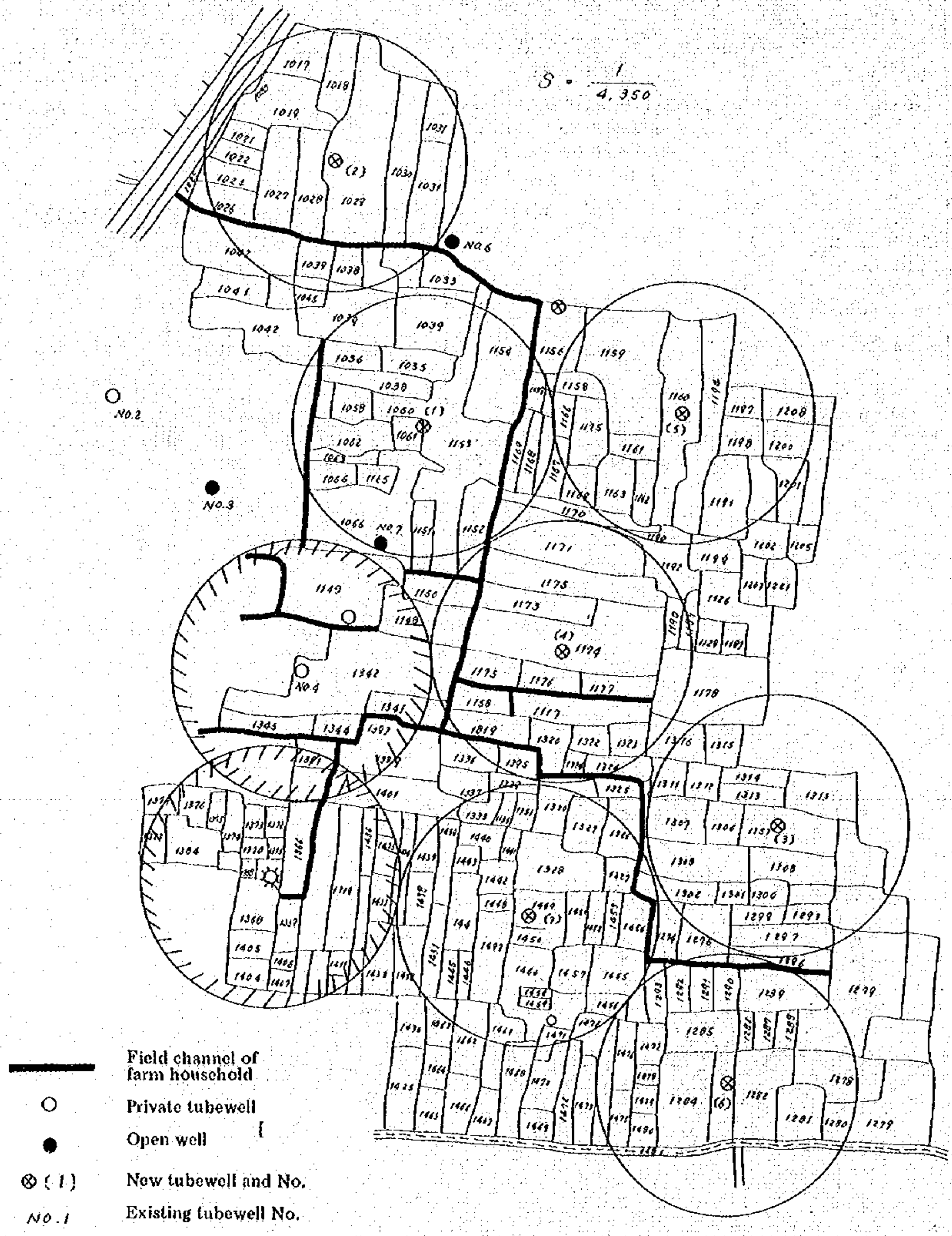


Fig. 10-3 LOCATION PLAN OF NEW TUBEWELL
(KATAR SUB-CENTER)



10.3 Katar

In Katar Sub-centre, there are 2 P.T.W.I.s. The average amount of water pumped is 0.009 m^3/sec as shown in Fig. 8-3 and Table 9-1. Accordingly, these two wells command an area of only 4.8 acres.

Proposed irrigation area by new tube wells is 9.52 acres, so that a total of 7 new wells should be drilled as shown in Fig. 10-1. The future distribution of tube wells shown in Fig. 10-3 is considered reasonable. It is believed that water can be smoothly conveyed through field channels except in the eastern hilly part.

10.4 Briefing of Preliminary Design

Under the water source development plan introduced above for respective sub-centres, 20 tube welss of Type 2 will be drilled as shown in Table 10-1. In addition, at least one observation well will be newly drilled in each sub-centre area for measurement of groundwater level and ground settlement.

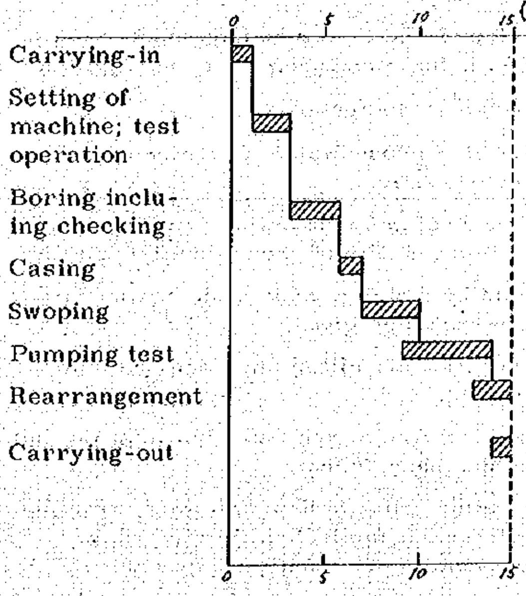
Consequently, a total of 23 new wells will be drilled.

10.5 Annual Drilling Plan

As shown in Fig. 10-4, construction period per tube well is set at 15 days. Water for mud water required for drilling work should be provided by the time when the drilling machines are delivered to the site. Though the drilling work itself can be completed in about 15 days, a period of at least 1 month will be required for setting up the pump room, pump house and pump set.

As already described, 20 new tube wells are planned to be drilled for pumping purpose. In addition, at least one observation well (2 - 3" in diameter, 100 m in depth, construction period - 15 days) will be drilled in each sub-centre.

Fig. 10-4 STANDARD DRILLING SCHEDULE FOR ONE TUBE WELL (100 M DEPTH, TYPE 2)



Remarks

Dail working hours: 8 hours; Actual working hours: 7 hours Avereage drilling speed: 6 m/hour; days required: 100 m/(7 hours x 6 m) 100 m/42 m = 2.5 days; checking days required: 0.5 days

N.S.T. screen is to be used, pastly using compressor.

1st day: preparation (preliminary pumping test); 2nd day: pumping test by stage; 3rd day to 5th day: pumping test for a fixed amount.

Remarks: 1. Water for boring (muddy water) is to be provided before the machine is carried.

2. Approximately one month is required after completion q drilling work for construction of pump room with concrete walls partly coated with water-tight materials and brick-made pumping house, and for setting up of pump and engine.

10.6 Future Survey Plan

Future survey plan and relevant problems brought to light by the present survey are briefed below.

(1) Sub-centres of Kulharia, Garhani and Katar, which were covered by the present survey, must resort to groundwater for the supply of irrigation water. Though the mission recommended Plan A as the best plausible plan because it promises eary management and also proposed Plan B as the second best in view of its economic advantage, these two plans and other alternative plans have their own merits and characteristics. Final choice between all these plans is therefore a matter that is left to the Indian government and farmers involved. In both Plans A and B, it is necessary that the tube well be provided with water-tight underground walls, and in addition, belt-driven equipment must be used. Thus, both plans present certain management and operation problems.

Whichever plan may be finally adopted, it is to be borne in mind that no hydro-geographical studies have been made to date to clarify how interference takes place and cause the decline of water level. At the stage of implementing construction work, therefore, hydraulic coefficients and hydro-geological data should be collected in order to be able to forecast the water level fluctuation by groundwater balance calculation and to check such fluctuation by actual observation. This is a must for effecting necessary and suitable revision to the entire plan.

(2) As already mentioned, comparative study should be made between groundwater and surface water for the long-term water source development in Shahabad district. To be more precise, groundwater balance in the vast groundwater valley should be analyzed for preparation of a water intake plan and rough calculation of construction cost. Results obtained from such analysis should then be compared with the surface water utilization plan which is to be separately prepared.

10.7 Problems in Project Implementation

(1) After the drilling work, electric detection should be carried out without fail, and the strainer position should be determined by making reference to the results of grain size analysis.

(2) Pumping test by stage and for a fixed quantity of water should be conducted, and hydraulic coefficients and influenced cirlce should be determined by actual measurement or calculation.

(3) At least one observation well should be drilled in each sub-centre area.

(4) At both observation wells and pumping wells, the trend of groundwater level fluctuation should be grasped by conducting daily and simultaneous observation.

(5) At observation wells, amount of ground settlment should also be observed. At the same time, soil test should be carried out in order to check the possibility of ground settlement.

(6) Groundwater balance calculation should be worked out by district, and on the basis of its results, forecast of future groundwater level fluctucation should be given.

(7) Indian technicians should be given training in the operation of drilling machines so that they will become technically capable of drilling work in future.

(8) It is necessary to train technical-administrative officials who are to take charge of groundwater utilization planning as well as tube well operation and management.

(9) Since tube wells will be jointly utilized by farmers, efforts should be made for promoting organized activities of farmers. At the same time, meetings should be held to give them explanation on the significance of the project and awaken them to the benefit of advanced farming.

(10) Since the current extension service has the nature of a pilot project, it bears closely on the success of future extension activities. It is to be noted that unless farmers feel that they are actually benefited by the extension activities now in progress, future extension activities will be made difficult. In this connection, arrangements should be made for exempting farmers from the depreciation expense or cost of machines, equipment and materials supplied from Japan.

(11) Allocation of construction work of irrigation facilities, method of procuring machines and equipment, farmers' burden ratio, repayment method, etc. should be determined in advance.

(12) For distribution of pumped water, existing facilities like field channel can be used. It will therefore be possible to convey water collected from a number of wells through a field channel. In such a case, it is necessary that an agreement on pumping operation be concluded between related irrigation associations or such associations be placed under the control of a newly established supervising agency.

(13) It is planned that in Garhani Sub-centre, 4 P. T. W. I. s will be abandoned and new tube wells will be drilled in their place. For this matter, it is necessary to obtain the consent of the owners and users of the said existing wells.

REFERENCE DATA 1

Prepared on April 14, 1972

Power rate

1. Reference: Electric Department of Arrah
   (through interview with assistant engineers)

2. Power rate

(1) For agricultural use:	Paisa 18/KW	(meter charge)
-do-	Rs. 3/month	(meter rent)
(2) For industrial use:	Paisa 20/KW	(meter charge)
-do-	Rs. 3/month	(meter rent)
(3) For commercial use:	Paisa 30/KW	(meter charge; below 100 KWH)
-do-	Paisa 35/KW	(meter charge; above 100 KWH)
-do-	Rs. 5/month	(fixed charge)
(4) For domestic use:	Paisa 30/KW	(meter charge; below 50 KWH)
-do-	Paisa 35/KW	(meter charge; above 50 KWH)
	not obtainable	(fixed charge)

3. Tentative power rate (only for agricultural use)

(1) When located within 100 feet from existing power line (440 Volt).	free of charge	
When located further than 100 feet from the enisting power line.	Rs. 3/foot	(charged to requester)

Besides the avove, the following charges and rales are applied.

(2) Security:	Rs. 40/HP	
(3) Service connection charge:	Rs. 100	(fixed)
(4) When transformed from existing power line(11,000 Volt)	Rs. 4,200/place	(average unit fee)
(5) When power exceeds 20 HP in case (4) above (above 20 HP at a place or above 5 HP at each of four places)	paid by government	
(6) When total amount of fees does not reach to the basic rate shown in (5), it is equalized by respective establishers.		

4. Example

Ex. 1: When power line (440 Volt) is within 150 feet, from a pump (12 HP), calculation is worked out as follows:

Rs. 3 x (150 - 100)	Rs. 150	Refer to 3-(1)
Rs. 40 x 12	Rs. 480	Refer to 3-(2)
	Rs. 100	Refer to 3-(3)
Total	Rs. 730	

Ex. 2: When power line (440 Volt) is within 80 feet from a pump (12 HP) calculation is worked out as follows:

Not applicable	nil	Refer to 3-(1)
Rs. 40 x 12	Rs. 480	Refer to 3-(2)
	Rs. 100	Refer to 3-(3)
Total	Rs. 580	

Remarks: Voltage ---------- 220 V for domestic use
440 V for general industrial use

REFERENCE DATA 2

Drilling Cost

Item	Ex. 1	Ex. 2	Ex. 3	Ex. 4	Ex. 5
Drilling diameter	8"	18"	6"	12"	24"
Diameter installed	6"	8"	4"	4"	8"
Authorities concerned	M.I.D.	L.I.D.	M.I.D.	M.I.D.	M.I.D.
Drilling cost per foot (1)	Rs.12.25	Rs.22.00	Rs.10.00	Rs.13.00	Rs.34.00
Cost of casing pipe per foot (2)	Rs.19.30	approx. Rs.40.00	Rs.10.76	Rs.10.76	Approx. Rs.40.00
Cost of strainer (3)	Rs.71.00 (brass-made)	Rs.54.60 (iron-made)	Rs.45.00 (brass-made)	Rs.45.00 (bross-made)	approx. (iron-made)
Cost for pipe insertion per foot (4)	Rs.2.00	Rs.3.00	Rs.1.50	Rs.1.50	Rs.3.00
Cost of bentonite per set (5)	Rs.150.00	Rs.300.00	Rs.0.00	Rs.200.00	Rs.300.00
Cost of gravel per cft (6)	Rs.2.50	Rs.2.50	Rs.0.00	Rs.2.50	Rs.2.50
Cost of pumping test per set (7)	Rs.450.00	Rs.450.00	Rs.350.00	Rs.350.00	Rs.600.00
Tuansportation	included in (1)	included in (1)	included in (1)	included in (1)	Rs.260.00
Cost of temporary housing (9) per set	Rs.400.00	Rs.400.00	Rs.0.00	Rs.400.00	Rs.650.00
Cost					
Cost of diesel engine per unit (10) /1	Rs.15,000.00 (10 HP)	Rs.22,000.00 (15 HP)	Rs.2,560.00 (5 HP) (centrifugal)	Rs.2,560.000 (5 HP) (centrifugal)	Rs.22,000.00 (15 HP)
Cost of pump	52.5 (centrifugal)	Rs.5,000.00 (bore hole pump without motor)			Rs.5,000.00 (bore hole pump without motor)

/1: 25% of the cost is subsidized.

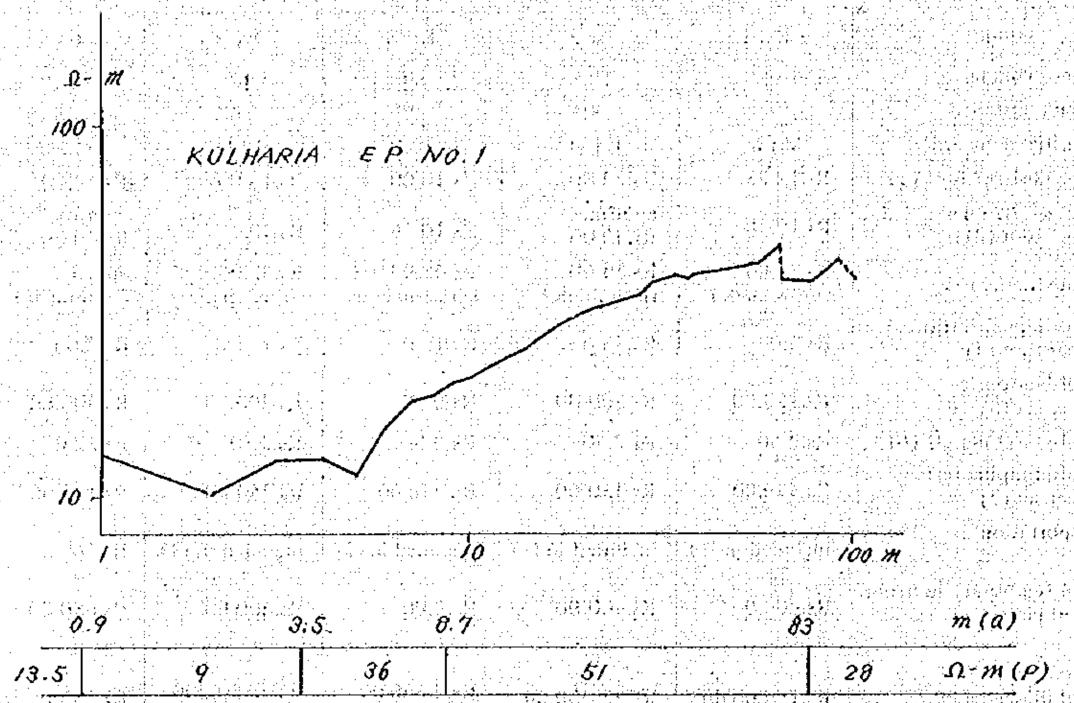
Condition: 1. Depth. . . . . 100 m (330')
2. Strainer . . . . 20 m (60')
3. Gravel filling . . . . 80 m (240')

Expenses

	Ex. 1	Ex. 2	Ex. 3	Ex. 4	Ex. 5
(1)	12.3X330=4,060	22X336=7,050	10X330=3,300	13X330'=4,280	34X330'=11,200
(2)	19.3X270=5,220	40X270=10,800	10.8X270=2,920	10.8X270=2,920	40X270=10,800
(3)	71X60=4,260	54.6X60=3,270	45X60=2,700	45X60=2,700	54.6X60=3,270
(4)	2X330=660	3X330=990	1.5X330=500	1.5X330=500	3X330=990
(5)	ft 150	300	0 0	200	300
(6)	2.50X0.15X240ft =90	2.50X1.4X240 =840	2.50X0=0	1.50X0.7X240 =420	2.50=2.8X240= =1,680
(7)	450	450	350	350	600
(8)	0	0	0	0	2,600
(9)	400	400	0	400	650
Sub-total	15,290	23,770	9,770	11,770	32,090
(10)	15,000 0	22,000	} 2,560	} 2,560	22,000
(11)	530	5,000			5,000
Sub-total	15,530	27,000	2,560	2,560	27,000
Total	30,820	50,770	12,330	14,330	79,090

Remarks: 1. 200 gpHP 199 grams per B.H.P. per hour
2. Parenthsized number is estimated.

REFERENCE DATA 3-1



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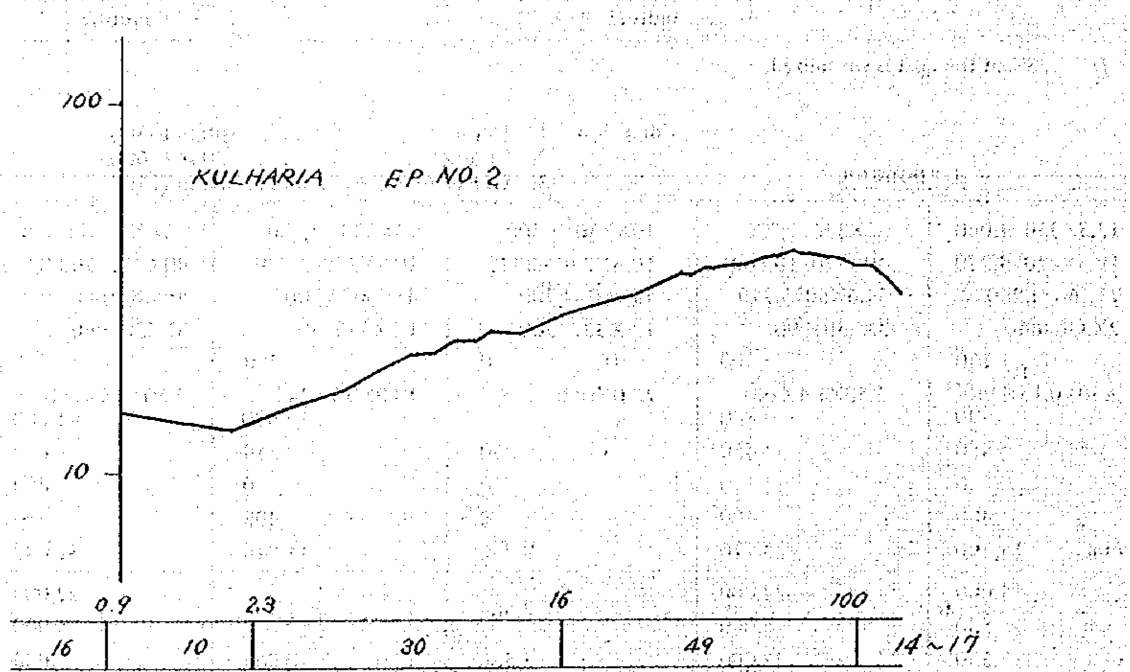

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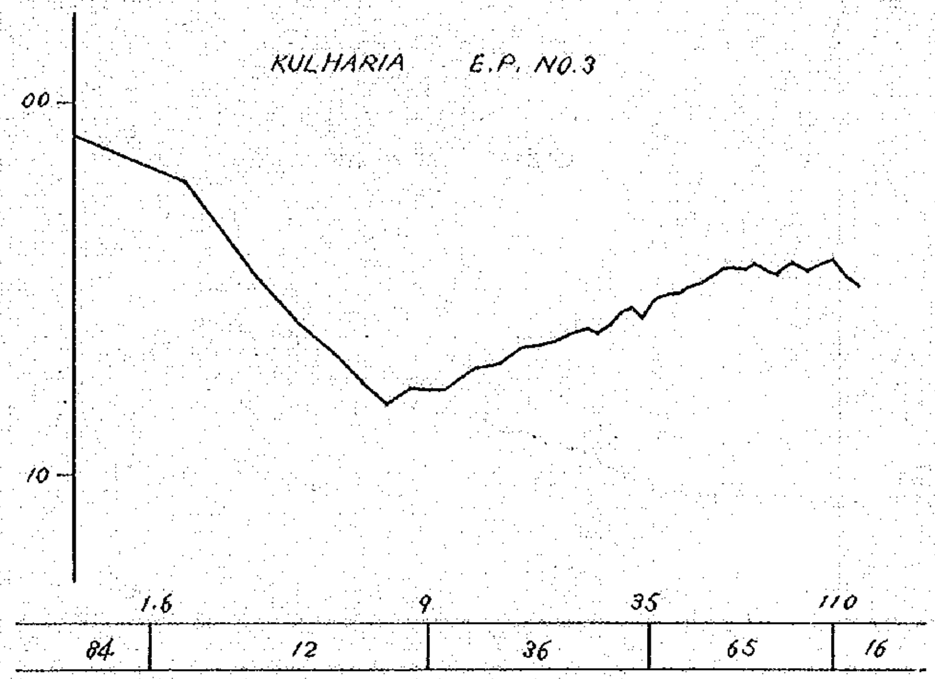

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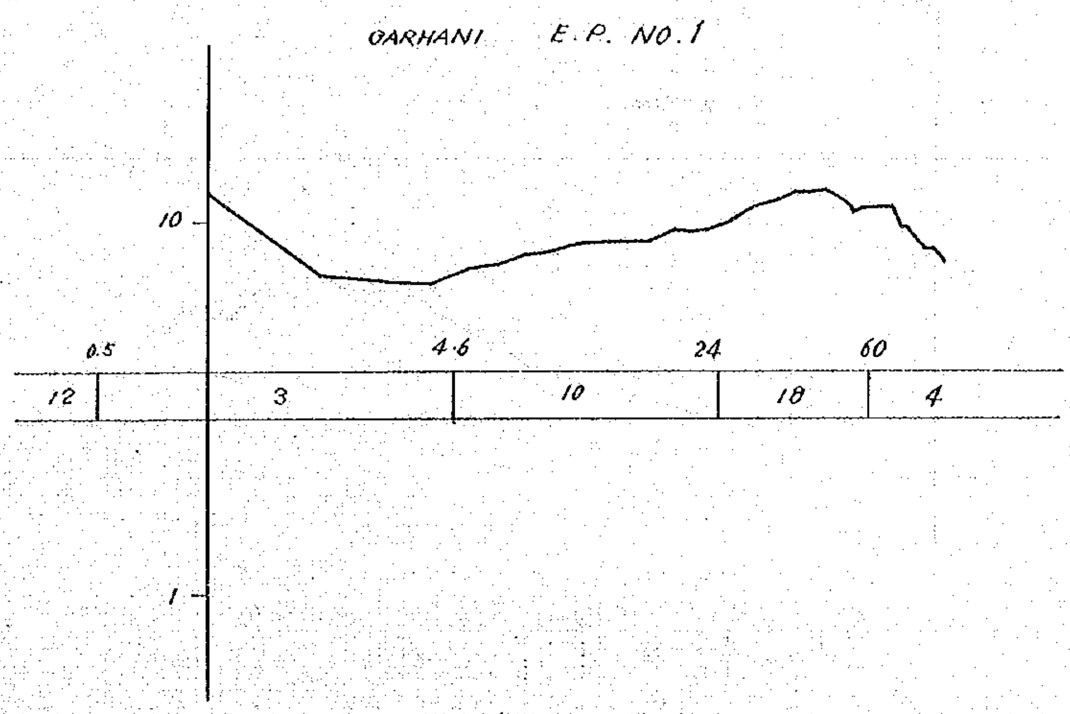

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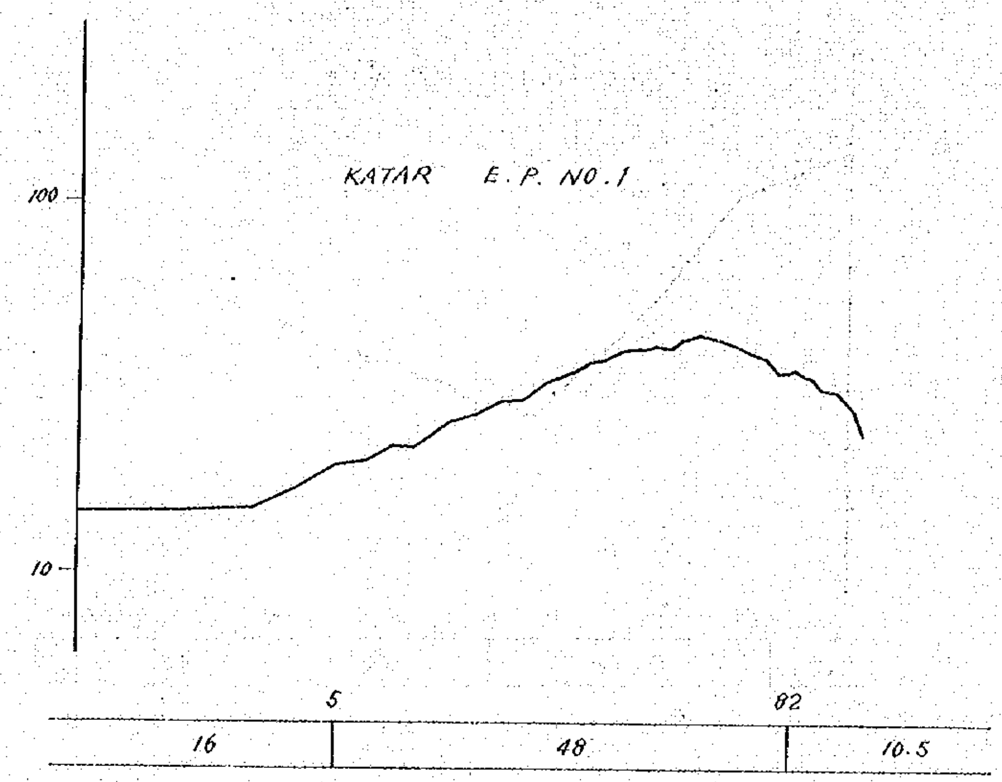

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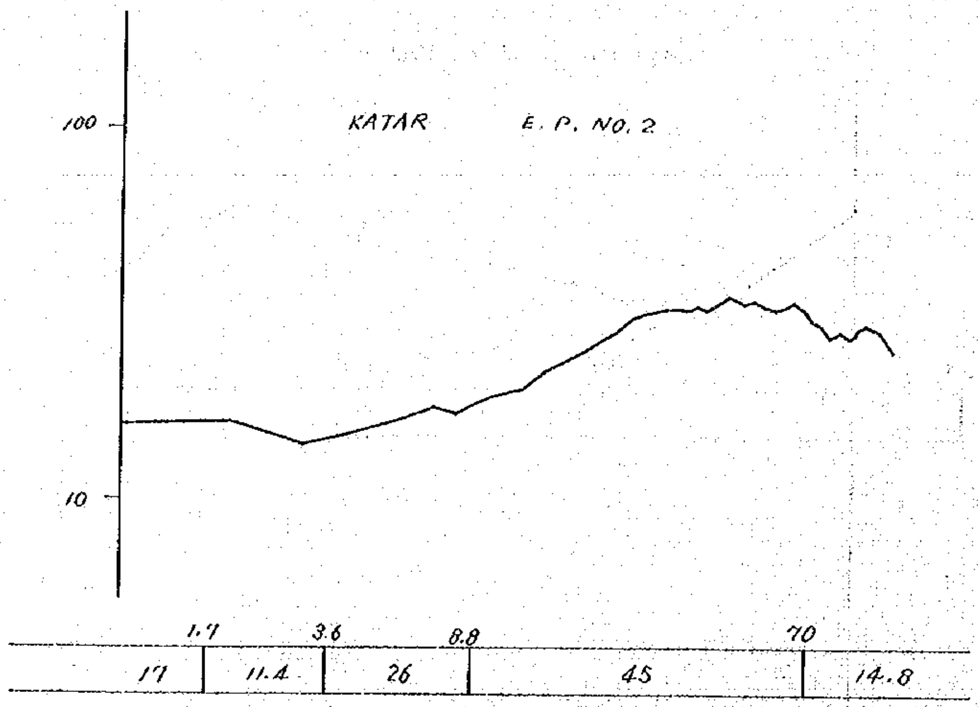
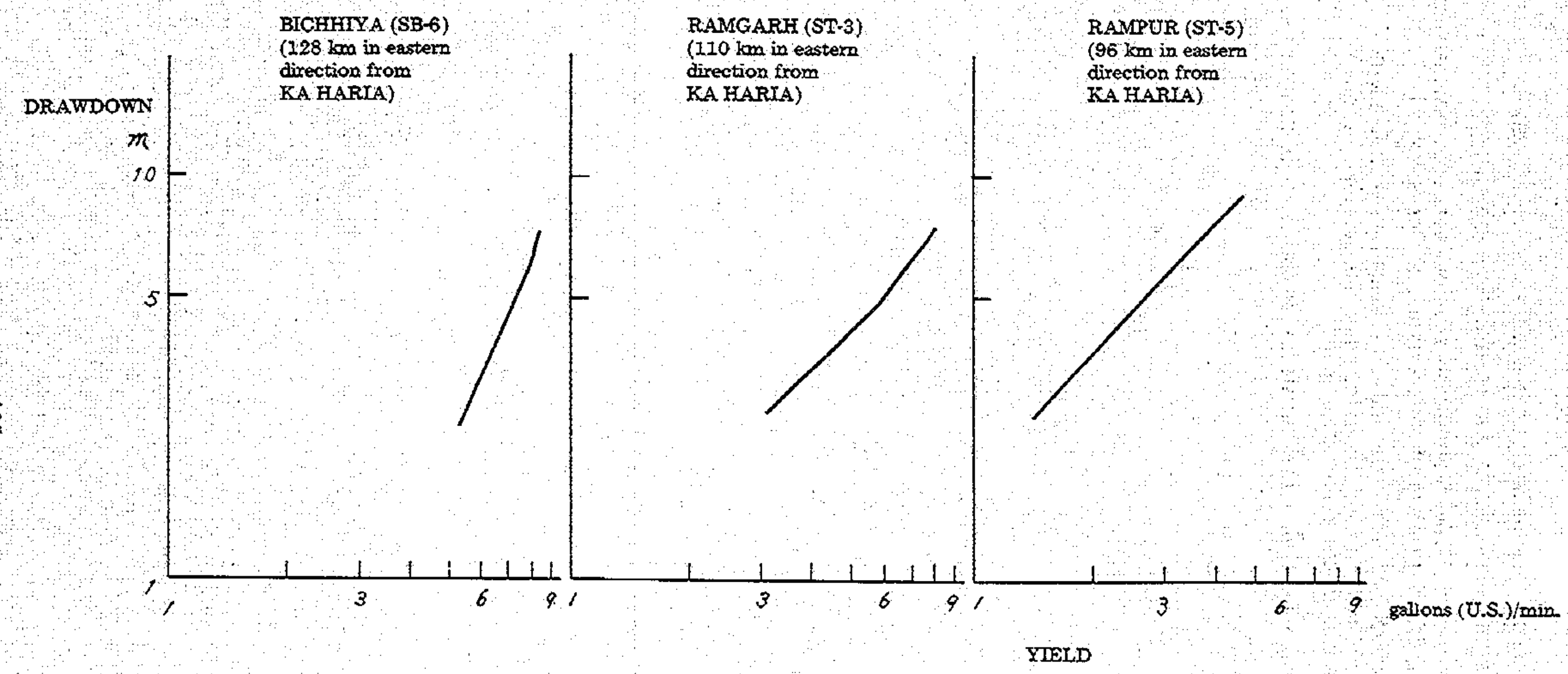


REFERENCE DATA 4 RECORD OF PUMPING TEST

(Refer to Bibliography 5)



BICHHIYA (SB-6)

N.W.L. 4.11 m
Yield: 2.83 m^3/min
S: 5.13 m
T: 330,400 gallons (U.S.)/day/ft
0.0489 m^2/sec
4.169 m/day
S: 0.0062
Depth of aquifer: 127-146 (rpm)

RAMGARH (ST-3)

N.W.L.: 5.30 m
Yield: 1.88 m^3/min
S: 4.14 m
T: 155,100 gallons (U.S.)/day/ft
0.0227 m^2/sec
14.57 m/day
S: 0.0755
Depth of aquifer: 70- 85
125-152 (48 m)
165-177

RAMPUR (ST-5)

N.W.L.: 7.38 m
Yield: 1.27 m^3/min
S: 6.26 m
T: 267,100 gallons (U.S.)/day/ft
0.0395 m^2/sec
33.70 m/day
S: 0.0022
Depth of aquifer: 67- 70
104-128 (520 m)
158-174

BIBLIOGRAPHY

1. Administration and Financing of Irrigation Works in India (1965)
2. Punjab National Bank (Shahabard); Lead - Bank Survey Report
3. Ray, D.K. and others: Groundwater Resources of Parts of Shahabard and Gaya Districts, Bihar (1966); Geol. Survey. Ind. Series B No. 23
4. Roy, A.K. and Sinha, Subrata: Groundwater Resources of Bihar with Special Reference to the Problems of Planning and Development for Irrigation Purposes (1968); Geol. Surv. Ind.
5. Agricultural Extension Centre (Arrah) (1972); Progress Report No. 2