2. EXISTING PROJECTS

Main existing groundwater development projects are described hereinafter.

(1) Groundwater Resources Investigation Project in Lumbini Zone

The details of the project were reported with "Groundwater Resource Investigation in Lumbini Zone, Western Terai, Nepal, USAID/NEPAL July 1973".

The project was conducted by USAID in collaboration with HMG/N during the period from 1969 to 1972 to evaluate the water-bearing properties in the alluvial deposits underlying in the Terai area of Lumbini Zone. Ninety-nine deep wells (average depth 150 m) were drilled in Kapilvastu and Rupandehi Districts and in a part of the Nawalparasi District. By the project, 14 production tubewells and 50 observation wells for monitoring purpose were drilled. In the groundwater development area, 42 tubewells including observation wells were drilled, but data and information on distinction between production and observation wells and monitoring records of observation well were not available.

The records of wells drilled in the project area are listed in Table B.1 and the location map of wells is illustrated in Fig. B.1.

(2) Kapilvastu Tubewell Project

In this project for which equipment was granted by the Japanese Government, tubewells were installed to investigate groundwater potential in Kapilvastu District. Project activity was started in 1982. Thirty-nine deep tubewells including observation wells and 40 shallow tubewells (including 23 wells assisted by UNDP in 1987) have been installed up to date. Of 39 deep tubewells, seven have been converted to production wells because of their large yield. The records and information of 17 shallow tubewells which were installed by HMG/N were not available excepting that those wells were installed as production wells in reply to farmers' demands in and around the upstream area of the Banganga River.

The investigation is to be finished in 1989 after installing additional six deep tubewells.

The records of deep and shallow tubewells are listed in Tables B.2.1, B.2.2 and B.3 respectively. The location maps of those wells are illustrated in Figs. B.1 and B.2.

(3) Others

1) Bairahawa-Lumbini Groundwater Project

The project supported by the World Bank is located at central area of Rupandehi District, on the north of Marchawar area but outside the Lumbini IRDP area.

The project is groundwater irrigation using deep tubewells. The target of Stage I (1976 - mid 1983) was to irrigate an area of 7,500 ha by digging 64 tubewells. Stage II (mid 1983 - present) which is now under implementation to dig 15 tubewells to irrigate an area of 1,800 ha.

2) Tubewell Water Use and Distribution Project

Main activities of this project, which is administered by the DOA, are to provide irrigation water to agricultural fields by using deep tubewells. Physical features of the project are similar to those of the Bairahawa-Lumbini Groundwater Project. Installation of 14 tubewells has so far been completed in the western part of Rupandehi District which is located on the west of the Bairahawa-Lumbini Project area and outside the Lumbini IRDP area.

3) Drinking Water Supply Projects

As drinking water supply project, three projects have been clarified as hereinafter.

- Terai Rural Water Supply and Sanitation Project (UNICEF),
- Drinking Water Supply Scheme (The Nepal Red Cross Society supported by The Japan Red Cross Society), and
- Primary Health Care, Drinking Water Supply Project (The Nepal Red Cross Society)

Several hundred shallow tubewells equipped with handpumps have so far been installed by each project in and around the project area.

Besides, there are some deep tubewells to supply drinking water to residents in town, some private tubewells(probably shallow tubewells), and considerably many traditional dugwells.

3. CONSTRUCTION OF WELLS FOR THE STUDY

3.1 General

Three tubewells were constructed by the Study Team to supplement the existing data and information.

The wells were primarily programmed in the depth of 180 m each but extended to 200 m in depth since the wells could not sufficiently meet the hydrogeological objectives by 180 m depth, i.e., the total thickness of aquifer where slotted pipe should be installed could not reach 50 m, designated total length of a slotted pipe.

3.2 Selection of the Sites

The sites of the three tubewells were selected in the following manner:

1) The site should be located in the area where groundwater potential shall be confirmed by deep tubewells to be drilled to supplement the existing data and information,

2) The site should be in the area where villagers highly demand drinking and/or irrigation water,

3) The site should be in the area where groundwater can be expected obtainable to some extent by a deep tubewell on the basis of the analysis of the existing data, and

4) The access to the site from a main road should not be so difficult.

Eventually, the following two sites were selected as illustrated in Fig. B.1.

1) For a pair of one pumping well (PW-1) and one observation well (OW-1), at Sitapur in Kapilvastu District, and

2) For the other test well (TW-1), at Marjadpur Village in Marchawar area in Rupandehi District.

After selection of the well sites, a local tender for the construction was performed and the contract was made with a local drilling firm.

3.3 Drilling and Well Construction

The drilling was commenced for an observation well (OW-1) in Sitapur Village on 26 November 1988 and completed with a test well (TW-1) in Marjadpur Village on 27 February 1989. Hydraulic feed rotary type drilling rig, TBM-70 with a diesel engine SD-33HP was used. Drilling programmes, geological logs, results of electrical resistivity logging, casing programmes, well structures, etc. are shown in Figs. B.3.1 to B.3.5, B.3.10 to B.3.12 and B.3.16 to B.3.19, and summarized as follows:

Well	Observation Well (OW-1)	Pumping Well (PW-1)	Test Well (TW-1)
Location	Sitapur Vil. Kapilvastu	Sitapur Vil. Kapilvastu	Marjadpur Vil. Marchawar
Commencement	26 Nov.1988	25 Dec.1988	12 Jan.1989
Completion	24 Dec.1988	30 Jan.1989	7 Feb.1989
Depth (m)	203.5	203.5	200.0
Diameter (in.)			
- Borehole	6-1/4	17-1/2 (60 m) 14-3/4 (143.5 m)	6-1/4
- Casing	3	8	3
Total screen length (Effective)	51 m (45 m)	54 m (47.5 m)	51 m (45 m)
Pumping test			
- Artesian flowing	12 lit./min	20 lit./min	300 lit./min
- Piezometric head	GL+1.3 m	GL+0.2 m	GL+7.75 m
- Discharge	234 lit./min	233.9 lit./min	461.4 lit./min
- Drawdown	GL-28.27 m	GL-39.05 m	GL-2.00 m
- Transmissivity (m^2/sec)	$1.39X10^{-4}$	$1.05X10^{-4}$	$3.09X10^{-3}$
- Storativity	$1.87X10^{-5}$	-	-
Drilling rig	TBM-70 Rotary type diesel engine SD-33HP		
Mud pump		Model MG-25W	
Casing pipe			
- Blank pipe	3" MS Type, ISI, t=4.3 mm plain end	10"&8" MS type, ISI, t=7.0 mm plain end	3" MS Type, ISI, t=4.3 mm plain end
- Reducer	-	10"X8" MS type, ISI, t=7.0 mm plain end 0.20 m	-
- Slotted screen pipe	3" MS Type, ISI, t=4.3 mm Saw cut slot, 1.6 mm X 75 mm Opening=12.0% L=51.0 m	8" MS Type, ISI, t=7.0 mm Saw cut slot, 1.6 mm X 75 mm Opening=12.6% L=54.0 m	3" MS Type, ISI, t=4.3 mm Saw cut slot, 1.6 mm X 75 mm Opening=12.0% L=51.0 m
Gravel packing	1.18-14 mm, 4 m^3, UC=2.5	1.18-14 mm, 20 m^3, UC=2.5	1.18-14 mm, 4 m^3, UC=2.7
Development			
- Cleaning	24 hours	24 hours	12 hours
- Bailing	36 hours	96 hours	24 hours
- Air lifting	12 hours	72 hours	24 hours
Pumping test			
- Step drawdown	-	53 hours	-
- Continuous	24 hours	72 hours	24 hours
- Recovery	16 hours	28 hours	5 sec.
Cement grouting & surface sealing	10 m below GL	10 m below GL	10 m below GL

3.4 Pumping Tests

Pumping tests were carried out to determine the hydraulic characteristics of the aquifer. Before the pumping tests, well developments were carried out for the purpose of removing underground resistance to flow. At first, the wells were cleaned by chemicals, lime sodium polyphsphate, and then developed in undermentioned method.

- Cleaning of the well,
- Bailing by bailer and serge block, and
- Air lifting by compressor.

Pumping tests were conducted using a pair of one pumping well (PW-1) and one observation well (OW-1), and using each one of three wells (PW-1, OW-1 & TW-1) besides. The results of pumping tests are illustrated in Figs. B.3.6 to B.3.9, B.3.13 to B.3.15, and B.3.20 to B.3.21, and summarized in the table before.

3.5 Water Quality Analysis

Water quality analysis were carried out on artesian flowing water samples from the three wells. It was entrusted to a local laboratory. The results of analysis are shown in Table B.4 and Figs. B.3.4, B.3.11 and B.3.18.

4. HYDROGEOLOGY

4.1 General

The Terai is the northernmost part of the Gangetic Plain within Nepal. Most of Terai forms the narrow, southern fringe of the country from 20 to 45 km wide, and shows a gentle depositional slope of alluvium which consists of clastics derived from the rising Himalayas.

The Terai, groundwater development area in the project area, is included in the Lumbini Zone of the Western Terai from the hydrogeological viewpoint. The Terai area is an alluvial plain which is bordered by the Siwalik ranges (Siwaliks) to the north and by India to the south. The elevation ranges from 90 to 130 m, however, it is almost flat in general though the tail areas of the Siwaliks have moderate slope.

The Siwaliks are formed by mountains of about 1,000 m high running east to west. They comprise the Siwalik formations (Si) which are molasse derived from the rising Himalayas and consist of sediment rocks of Miocene to Pleistocene Ages. The Siwalik formations form a basement of the alluvial deposits in the Terai area.

The Terai area is composed of debris flow deposits (alluvial deposits) which were carried by river water running from the Siwaliks. Groundwater in the Terai area is recharged mainly by the river water. There are two main perennial rivers, namely the Banganga and the Tinau, in the groundwater development area. These two rivers, however, have their origins in the mid-Siwaliks or Middle Mountains and are minor rivers in Nepal compared with other major rivers which have their origins in the High Mountains or High Himal and run across the Terai.

Other small rivers in the area have their origins on the southern slope, facing to the Terai area, of the Siwaliks and almost dry up in the dry seasons.

The alluvial deposits in the Terai area are divided into two, namely the older alluvial deposits (Oa) and the young ones (Ya). The former's distribution area forms the upland which nearly corresponds to the forest area. The latter is formed by eroding the former, and is being deposited on it. The large part of the latter's distribution area corresponds to the flood areas seen during the monsoon seasons. The latter forms typical fans at the entrance points where the Banganga and the Tinau flow into the Terai area from the Siwaliks.

The alluvial deposits in the Terai area consist of a large amount of coarse-grained materials such as boulder, cobble and pebble which form good aquifers in the north, and fine materials such as sand, silt and clay in the south. However, each bed of the alluvial deposits in the Terai area is thin; its continuity is poor and its geological log is extremely variable. According to the existing data, the beds of coarse-grained materials forming good aquifers in this Terai area are especially thin and poor in continuity compared with those in other Terai. It is probably because of that there is no large rivers in this Terai area.

4.2 Unconfined Aquifer (Phreatic Aquifer)

The unconfined aquifer is distributed throughout the Terai area. The lower limit of the aquifer is not defined clearly, but the depth of it is presumed to be up to 30 m below the groundwater surface. The aquifer consists of alternating beds of clay, silt, fine sand and thin stringer of gravel. Generally, permeability of the aquifer is low.

The unconfined aquifer has been tapped by many dugwells to supply water for domestic use and irrigation.

Groundwater Flow Pattern

In the area, there are many dugwells of which 26 dugwells in Kapilvastu District have been monitored by HMG/N since November 1987. The location map and records of the dugwells monitored is illustrated in Fig. B.4 and shown in Table B.5. Several dugwells in Kapilvastu District and Marchawar area were observed by the Study Team.

According to the monitoring records, almost all of dugwells show the lowest water levels in July, and the highest in October, every year.

Isobath map of the water table is illustrated in Fig. B.4 which was observed in July 1988 when almost dugwells showed the lowest levels. The configuration of the isobath lines suggests that groundwater flows regionally from north to south and that the Banganga, the Tinau and the other small rivers charge the unconfined groundwater.

Change in Water Table

The water table of dugwells fluctuates considerably by season and shows sensitive response to rainfall. According to the existing data, the highest water level is observed during from middle to end of a rainy season and it reaches 0.5 m to 1.5 m below ground surface in case of the highest. The difference of the water level between the lowest and the highest is 2.9 m on an average. Generally, the difference is large in the northern area and small in the south of the project area.

Water Quality

Water quality analysis was carried out on water samples which were taken by the Study Team from seven wells and one spring. The results of the analysis are shown in Table B.6. According to the table, the items being out of the international standards for drinking water of WHO are as follows:

- Total hardness (more than 500 mg/lit.) : No.1
- Chloride (more than 250 mg/lit.) : No.1

Though the other items are cleared by the standards of WHO, the values of pH show that water is slightly alkaline, and the higher values of total hardness and total ammonia indicate that water is moderately hard and is polluted slightly. Furthermore, as the values of total solids are higher, if the water is used without treatment, the water will be:

- Not tasty to drink,
- Easy to be scaled, and
- Not suitable for washing clothes.

4.3 Confined Aquifer

The presence of confined aquifer is widely known in the area. The upper limit of the aquifer is presumed to be 40 m and more below the ground surface. The aquifer consists of coarse sand and gravel beds intercalated by thick clay layers. The confined aquifers, tapped by the existing deep tubewells, give the artesian flowing zones as illustrated in Fig. B.5. According to the figure, there are two main artesian flowing zones which occupy a wide area of the groundwater development area.

It is considered that major artesian aquifers exist in the layers of 40 to 60 m deep and 150 to 160 m deep. The former is dominant in the northern highland, and the latter in the southern lowland.

According the tubewells' data obtained, the piezometric heads are within 4 m in most cases and more than 10 m in rare case, and it's discharge shows a large deviation from place to place, ranging from several liters to several hundred liters per minute, and over 1,000 liters per minute in some places.

Groundwater Flow Pattern

The contour map of piezometric surface was prepared based on data of water levels of existing deep tubewells and is illustrated in Fig. B.6. These water levels were recorded at the time of drilling.

The configuration of the contour map shows that groundwater flows through the artesian aquifer from north to south with an average gradient of 1:1,500. Artesian aquifers seem to be recharged with infiltrated water at the fan area such as in the upstream of the Banganga River and Tinau River and is under sufficient pressure to bring water into the wells in and around the groundwater development area.

Aquifer Characteristics

Several water bearing beds have been found so far in the groundwater development area. However, yield of water varies among them. Some of gravel or coarse sand beds yielding less quantity of water are believed to be lenticular-shaped without direct connection to upstream of the Banganga River, the Tinau River and other small rivers.

Groundwater potential map prepared based on the data of deep tubewells installed in Kapilvastu Tubewell Project area and this JICA project area is illustrated in Fig. B.6. Groundwater potentiality in the map is divided into three, as given below.

- High potential area:
  Transmissivity is in the range of 10^{-2} m^2/sec

- Moderate potential area:
  Transmissivity is in the range of 10^{-3} m^2/sec

- Low potential area:
  Transmissivity is in the range of 10^{-4} m^2/sec

Water Quality

Water quality analysis was carried out on artesian flowing water samples from the three wells installed by the Study Team. The results of analysis are shown in Table B.4 together with existing data provided by USAID. According to the table, the items being out the international standards for drinking water of WHO are as follows:

- pH (out of 6.5-8.5) : Nos. 8, 12 & 13
- Total iron (more than 0.3 mg/lit.) : Nos. 1, 2 & 3

Though the other items clear the standards of WHO, the values of pH and the higher values of total hardness indicate that water is slightly-moderately alkaline and moderately hard. Ammonia is detected in the sample of Nos. 1, 2 & 3; however it might have been due to not pollution but to natural aquifer conditions of deoxidized because of the confined water. As the values of total solids are higher, if the water is used without treatment, the water will be:

- Not tasty,
- Easy to be scaled, and
- Cause of red-colored water (because of the higher value of iron)

5. POSSIBILITY OF GROUNDWATER EXPLOITATION

5.1 General

To study the possibility of groundwater exploitation in the area, the following data were mainly utilized:

1) Data of wells installed by HMG/N for Kapilvastu Tubewell Project.
2) Data of wells installed by JICA, February 1989.

In this course, three kind of potential areas such as High Potential Area, Moderate Potential Area and Low Potential Area were selected and studied in detail. The results of the study are summarized in Table B.7.

Definition of each well is as given below:

<u>Definition of Well</u>

- Deep tubewell:
  70 - 200 m in depth.
  Study was conducted at 200 m in depth and eight inches in diameter.
  In the layers below 200 m, better aquifers seem to be little.

- Shallow tubewell:
  30 - 70 m in depth.
  Study was conducted at 70 m in depth and eight inches in diameter.

- Hand pump well:
  Up to 30 m in depth.
  Study was conducted at 30 m in depth and four inches in diameter.

5.2 High Potential Area

This area extends in the north of Banganga as shown in Fig. B.6. The transmissivity is $3.74X10^{-2}$ m^2/sec, the top level of screen is 43 m below ground surface and the screen length is 31 m in the case of 135 m deep wells on an average.

Deep Tubewell

Screen length (Sl) to be installed between 135-200 m in depth is 22 m (*1), then the total screen length (St) of 200 m deep wells is 53 m (*2). Therefore, the transmissivity (T) in case of the 200 m deep well is calculated at $6.4X10^{-2}$ m^2/sec (*3).

Note: (*1) Sl = (200-315) X 31/(135-43) = 22 m

(*2) St = 31 + 22 = 53 m

(*3) T = $3.74 X 10^{-2} X 53/31 = 6.4 X 10^{-2}$ m^2/sec

Here, it was presumed that the same average coefficient of permeability is eventually distributed in the aquifer of 135 m to 200 m deep. Furthermore, it was presumed that the storativity(S) is 5.0X10-3 which was applied as a general value of the storativity due to the lack of available data, and the value is smaller than the transmissivity, by about one power. Pumping hours, drawdown and radius of influence are shown in the following table, by the calculation using Theis' formula.

Discharge		12 hours
50 lit./sec	Drawdown (m)	1.12
	Radius of influence (m)	900
40 lit./sec	Drawdown (m)	0.90
	Radius of influence (m)	900

If a pumping method limits that the drawdown and the radius of influence be about 10 m and about 1,000 m respectively, 50 lit./sec of discharge is expected through 12 hours, and at that moment the drawdown is calculated at about 1.1 m and the radius of influence is calculated at 900 m.

Shallow Tubewell

As described above, screen length to be installed between 43-135 m in depth is 31 m; and the total screen length (St) of 70 m deep well is 9.1 m (*1). Therefore, the transmissivity (T) of the 70 m deep well is calculated at $1.1 X 10^{-2}$ m^2/sec (*2).

Note: (*1): St = 31 X (70-43)/(135-43) = 9.1 m

(*2): T = $3.74 X 9.1/31 = 1.1 X 10^{-2}$ m^2/sec

As the storativity (S) is presumed to be 1.0×10^{-3}, pumping hours, drawdown, and radius of influence calculated by using Theis' formula are as shown in the following table.

Discharge		12 hours
50 lit./sec	Drawdown (m)	6.51
	Radius of influence (m)	900
40 lit./sec	Drawdown (m)	5.21
	Radius of influence (m)	900

Fifty liter per second of discharge is expected through 12 hours, and at that time the drawdown is calculated at about 6.5 m, and the radius of influence at 900 m.

5.3 Moderate Potential Area

This area extends widely in the south of Banganga, in the west and the south-west of the project area, and in Marchawar as shown in Fig. B.6. According to the available data, the average value of transmissivity is 3.94×10^{-3} m^2/sec.

Deep Tubewell

The transmissivity (T) in the case of 200 m deep well is calculated at 6.7×10^{-3} m^2/sec (*1). Here, it is presumed that the storativity (S) is 5.0×10^{-4}. In this area, the discharge, pumping period, drawdown and radius of influence are calculated and shown in the following table:

Note: (*1): $T = 3.94 \times 10^{-3} \times 53/31 = 6.7 \times 10^{-3}$ m^2/sec

Discharge		12 hours
50 lit./sec	Drawdown (m)	10.7
	Radius of influence (m)	900
40 lit./sec	Drawdown (m)	8.55
	Radius of influence (m)	900

Judging from the above table, it is expected that 40 lit./sec of water will be pumped up through 12 hours in this area, and at the same time the drawdown and the radius of influence will be about 9.0 m and 900 m respectively.

Shallow Tubewell

The transmissivity (T) in the case of the 70 m deep well is 1.2×10^{-3} m^2/sec (*1). Here, it is presumed that the storativity (S) is 1.0×10^{-4}. In this case, the discharge, pumping period, drawdown and radius of influence are calculated and shown in the following table:

Note: (*1): $T = 3.74 \times 10^{-3} \times 9.1/31 = 1.2 \times 10^{-3}$ m^2/sec

Discharge		12 hours
15 lit./sec	Drawdown (m)	17.9
	Radius of influence (m)	900
10 lit./sec	Drawdown (m)	11.9
	Radius of influence (m)	800

Judging from the above table, in this area it is expected that 10 lit./sec of water is pumped up through 12 hours, and at that time the drawdown and the radius of influence are calculated by about 12 m and 800 m respectively, in the High and Moderate potential areas.

5.4 Low Potential Area

This area extends widely in the project area other than the high and moderate potential area as shown in Fig. B.6.

According to the available data, the average value of transmissivity is 4.01×10^{-4} m^2/sec.

Deep Tubewells

The transmissivity (T) of 200 m deep well is calculated at 6.9×10^{-4} m^2/sec (*1). It is presumed that the storativity (S) is 5.0×10^{-5}. In this area, the discharge, pumping period, drawdown and radius of influence are calculated and shown in the following table.

Note: (*1): $T = 4.01 \times 10^{-4} \times 53/31 = 6.9 \times 10^{-4}$ m^2/sec

Discharge		12 hours
25 lit./sec	Drawdown (m)	51.9
	Radius of influence (m)	900
10 lit./sec	Drawdown (m)	20.8
	Radius of influence (m)	900

As seen in the table the drawdown reaches 20.8 m even under discharge of 10 lit./sec and pumping operation continues 12 hours long.

Shallow Tubewell

In the case of shallow tubewells, the transmissivity (T) is calculated at 1.2 X 10-4 m^2/sec (*2).

Note: (*2): $T = 4.01 \times 10^{-4} \times 9.1/31 = 1.2 \times 10^{-4}$ m^2/sec

Discharge		12 hours
10 lit./sec	Drawdown (m)	119.4
	Radius of influence (m)	900
5 lit./sec	Drawdown (m)	59.7
	Radius of influence (m)	900

As seen in the table, the drawdown reaches about 60 m even under the conditions that 5 lit./sec of water is pumped up through 12 hours. Judging from the above, in this area it is concluded that discharge by power-driven pump is inadequate, and it is better to use hand pumps mainly for the phreatic groundwater existing in the shallow layers above 30 m.

If transmissivity (T) and porosity (S) of the phreatic aquifer are 1.0×10^{-5} m^2/sec and 0.25 respectively and the diameter of well is 4 inches (0.1 m), the discharge and others are calculated in the following table.

Discharge		12 hours
1.0 lit./sec	Drawdown (m)	59.7
	Radius of influence (m)	22
0.2 lit./sec	Drawdown (m)	11.9
	Radius of influence (m)	90

5.5 Number of Wells and Prospective Quantity of Water

On the basis of the study in 5.2, 5.3 and 5.4, the prospective quantity of water in respective areas is shown in the following table and details is shown in the Table B.8. It is expected that water of 40-50 lit./sec. will be possible from one deep tubewell by pumping-up, in the High and Moderate Potential areas.

Number of Wells and Prospective Quantity of Water

	Pumping (lit./sec/hrs.cycle)	Area (km^2)	Well Number to be Constructed (nos.)	Existing Well (nos.)	Proposed Well Number (nos.)	Proposed Discharge (m^3/day)
High Potential Area						
North Banganga R. Area	50 / 12	30.6	12	4	8	17,000+
	50 / 12		12		8	17,000+
South Banganga R. Area	50 / 12	19.4	7	19	-	-
	10 / 12		9		-	-
Moderate Potential Area						
Westen Area	50 / 12	40.0	15	7	8	17,000
	10 / 12		19		12	5,000
South-Western Area (Krishnanagar)	50 / 12	29.2	11	5	6	12,000
	10 / 12		14		9	3,000
Marchawar Area	50 / 12	22.8	8	1	7	15,000
	10 / 12		11		10	4,000
Low Potential Area						
Remained Area	Hand Pump			67+		
Total			53	103+	29	61,000+
			65		39	29,000+

Note :
1) "Existing Well" includes both deep and shallow tubewells.
2) In "High Potential Area", "Moderate Potential Area" and "Total" columns, a case of deep tubewell is indicated in upper part and a case of shallow tubewell is in lower part respectively.

6. STANDARD DESIGN OF WELL

6.1 Well Depth and Diameter

In the area, major artesian aquifers exist in the layers of 40 to 60 m deep and 150 to 160 m deep; on the other hand, in the layers deeper than 200 m, suitable aquifers seem to be little. Therefore, the depth of deep tubewells is recommended to be up to 200 m below ground surface. For the discharge of 20 to 50 lit./sec, the upper part of 12 inches casing (pump chamber) and the lower part of 8 inches casing are recommended.

6.2 Well Structure

The structure of the proposed deep tubewell is illustrated in Fig. B.7. The upper section of the well cased by 12 inches pipe is provided with a pump capable of delivering 20 to 50 lit./sec. The lower section is also cased by 8 inches pipe and equipped with screen with total length of more than 53 m (more than 9.1 m in the case of a shallow tubewell). The upper section will require depth of 50 m for fall-down of water level in future in the case of deep tubewells.

The grain size of the aquifer to which the screen is to be positioned is not known, however, in view of the fact that the pumped water of the existing and new deep tubewells which have been constructed by the Study Team contain a small quantity of fine sand, the wire-wound type screen with slit aperture of 0.5 mm or less (10-13% of opening ratio) is recommended to prevent the sand from flowing into the well. The annular space between bored wall and casing or screen is to be filled with gravel of selected size from 2 mm to 10 mm.

TABLES

Table B.1 Record of Deep Tubewells by USAID (1969-1972)

	Well No.	Location		Ground Elevation (m)	Total Depth (m)	Casing Diameter (inch)	S. W. L. (Below G.L: m) (Elevation: m)	Screen Length (m) (Top Level - Bottom Level Below G.L: m)	Discharge (l/min) Pumping	Discharge (l/min) Artesian Flowing	Drawdown (m)	Transmissivity (m^2/sec)	Storativity	Remarks
1	6/1	Jigna	Harchawar	91.4	285.0	uncased	-	-	-	-	-			
2	6/2	Sombarsa	Harchawar	89.3	99.0	uncased	-	-	-	-	-			
3	6/3.4	Bogri	Harchawar	95.3	153.0	8 (0.0~37.2)	2.97 (92.33)	6.0 (30.0- 36.0)	189.3		2.1	$1.57\sim1.84\times10^{-4}$	$2.16\sim3.93\times10^{-4}$	
4	6/5	Nuwadiha	Harchawar	96.2	166.8	uncased	-	-	-	-	-			
5	8/1	Karidaha		94.5	150.6	1 1/2 (0.0~99.0)	+0.60 (95.10)	3.0 (90.0- 93.0)		11.4				
6	8/2.3	Mughla		102.7	296.1	6 (0.0~159.0)	+11.70(114.40)	6.0 (150.0-156.0)		1,268.8		$1.69\sim2.75\times10^{-4}$	$1.1\times10^{-3}\sim3.25\times10^{-4}$	
7	8/4	Sarahawa		106.7	150.0	3 (0.0~42.0)	+3.30(110.00)	3.0 (36.0- 39.0)		22.7				
8	8/5	Asnia		113.9	120.9	3 (0.0~74.4)	+11.10(125.00)	4.8 (66.6- 71.4)		435.3		3.62×10^{-4}		
9	8/6	Sitlapur		130.7	3.9									* Abandoned hole
10	9/1	Chakacouda		95.3	295.5	uncased	-	-	-	-	-			
11	9/2	Damraha		102.9	168.0	3 (0.0~63.0)	+0.6(103.50)	3.0 (58.5- 61.5)		7.6				
12	9/3.4.5	Rehara		109.1	150.0	8 (0.0~37.8)	1.50(107.60)	3.0 (33.3- 36.3)	189.3		3.9	$9.38\sim9.69\times10^{-5}$	9.35×10^{-5}	
13	9/6	Wadari		115.7	150.9	uncased	-	-	-	-	-			
14	9/7.8	Motipur		120.1	150.6	8 (0.0~51.6)	+8.70(128.80)	8.1 (40.8- 48.9)		2,339.1		$7.73\sim7.99\times10^{-4}$	1.01×10^{-4}	
15	9/9													* No data
16	10/1	Bakapur		100.3	151.5	uncased	-	-	-	-	-			
17	10/2.3	Taulihawa		103.5	210.0	10 (0.0~29.4) 6 (29.4~156.0)	+2.40(105.90)	4.2 (150.0-154.2)	136.3	75.7	-	$2.72\sim2.90\times10^{-5}$	$1.25\sim1.67\times10^{-4}$	
18	10/4	Janakpur		107.5	150.6	uncased	-	-	-	-	-			
19	10/5	Gorsinghi		121.4	150.6	3 (0.0~65.4)	+1.50(122.90)	3.6 (58.8- 62.4)		18.9				
20	10/6	Bhelai		133.4	150.9	3 (0.0~43.5)	+0.60(134.00)	3.6 (36.3- 39.9)		7.6				
21	11/1	Paraspur		98.4	150.6	uncased	-	-	-	-	-			
22	11/2	Gaidahawa		102.1	150.6	3 (0.0~57.0)	+1.50(103.60)	4.5 (49.5- 54.0)	189.3		-			
23	11/3	Bankatti		105.1	150.6	uncased	-	-	-	-	-	8.54×10^{-5}		
24	11/4	Bhaktapur		131.0	235.5	uncased	-	-	-	-	-			
25	11/5	Champapur		115.5	150.0	3 (0.0~57.6)	+3.90(119.40)	3.0 (53.1- 56.1)		49.2				
26	12/1	Ajigara		104.2	279.9	uncased	-	-	-	-	-			
27	12/2	Bahadurganj		107.2	74.4	10 (0.0~29.4) 6 (29.5~54.3)	6.90(100.30)	3.0 (51.3- 54.3)	Slight					
28	12/3	Gameshpur		113.0	150.6	uncased	-	-	-	-	-			
29	12/4.5	Dharamnagar		123.7	150.6	6 (0.0~64.5)	+4.50(128.20)	5.1 (57.6- 62.7)		98.4		$7.09\sim8.58\times10^{-5}$		
30	12/6	Rahatkol		131.0	150.6	uncased	-	-	-	-	-			
31	13/1	Krishnanagar		101.8	84.0	10 (0.0~27.0) 6 (27.0~53.1)	4.50(97.30)	3.0 (48.6- 51.6)	159.0		8.1			
32	13/2	Shivanagar		102.8	150.0	8 (0.0~27.0) 6 (27.0~68.7)	4.80(98.00)	4.2 (62.4- 66.6)	159.0		6.0	1.71×10^{-4}		
33	13/3							.						* No data
34	13/4	Pipri		114.3	150.6	3 (0.0~54.3)	+0.30(114.60)	2.4 (50.4- 52.8)		3.8				
35	13/5	Lohraula		130.5	150.9	uncased	-	-	-	-	-			

Table B.2.1 Record of Deep Tubewells by Kapilvastu Tubewell Project, HMG/N (1982-1988)(1/2)

	Well No.	Location	Ground Elevation (m)	Total Depth (m)	Casing Diameter (inch)		S. W. L (Below G.L m)	Screen Length (m) (Top Level - Bottom Level) (Below G.L: m)	Discharge (l/min)		Drawdown	Trans-missivity	Storatirity	Remarks
					Pump Housing (Below G.L: m)	Screen			Pumping	Artesian Flowing				
1	K-1	Ganesnpur		132.0	10 (38.20)	6	-	25.70 (43.80-115.80)	-		-	-		
2	K-2	Pipri		117.0	10 (38.40)	6	3.70	22.20 (52.12- 85.42)	-		-	-		
3	K-3	Bahadurganj		123.0	10 (33.17)	6	6.70	29.50 (33.17-119.00)	417.5		17.61	5.21×10^{-4}		
4	K-4	Khamaria		94.0	10 (33.90)	6	5.83	17.61 (-)	220.4		18.84	1.72×10^{-4}		
5	K-5	Unaulia		97.0	10 (32.83)	6	2.78	17.83 (-)	91.9		17.72	4.75×10^{-4}		
6	K-6	Balampur		105.0	10 (36.33)	6	-	18.32 (-)	-		-	-		
7	K-7	Gurchihawa		145.0	10 (32.17)	6	5.85	23.50 (40.00-131.00)	676.4		14.40	3.75×10^{-3}		
8	K-8	Baluhi		155.0	10 (31.18)	6	3.52	36.16 (-)	334.0		14.80	1.02×10^{-3}		
9	K-9	Shivanagar		122.0	10 (31.50)	6	5.93	38.50 (59.0 -112.50)	1,152.3		11.80	5.86×10^{-3}		
10	K-10	Pipra		147.0	10 (31.80)	6	-	33.30 (46.00-141.50)	-		-	-		
11	K-11	Ramwapur		136.0	10 (32.00)	6	7.46	44.80 (54.00-135.00)	804.9		10.54	4.63×10^{-3}		
12	K-12	Bhitwa		147.0	10 (38.50)	6	-	38.50 (-)	-		-	-		
13	K-13	Motinagar		153.0	10 (31.00)	6	A	22.00 (33.50- 75.00)	1,169.0	2.3	17.55	8.91×10^{-3}		
14	K-14	Behuwa		150.0	10 (34.80)	6	3.08	27.50 (37.00- 82.50)	124.1		8.39	9.96×10^{-4}		
15	K-15	Parsiya		146.0	10 (32.30)	6	1.50	33.00 (33.00-141.00)	-		-	-		
16	K-16	Mahuli		144.0	10 (31.50)	6	A	38.50 (31.50-121.00)	985.3		11.82	3.00×10^{-3}		
17	K-17	Lalpur		143.0	10 (32.50)	6	2.10	38.50 (50.00-116.00)	309.0	2.0	15.90	2.11×10^{-4}		
18	K-18	Derwa		147.0	10 (37.50)	6	3.50	55.00 (47.50-115.50)	343.9		16.60	2.86×10^{-4}		
19	K-19	Thunia		125.0	10 (37.70)	6	3.70	33.00 (34.00- 75.50)	385.8		18.00	4.79×10^{-3}		
20	K-20	Sarwa		128.0	10 (30.50)	6	3.22	38.50 (32.00- 94.00)	1,404.5		16.95	5.71×10^{-3}		
21	K-21	Banda		153.0	10 (40.30)	6	3.70	44.00 (51.00-105.00)	397.3		20.97	1.64×10^{-3}		
22	K-22	Chanaiau		83.0	10 (34.30)	6	4.10	27.50 (34.00- 67.00)	107.4		18.80	1.60×10^{-3}		
23	K-23	Deuri		138.0	10 (36.00)	6	4.04	33.00 (36.00-104.00)	50.9		9.30	1.08×10^{-3}		

Table B.2.2 Record of Deep Tubewells by Kapilvastu Tubewell Project, HMG/N (1982-1988)(2/2)

	Well No.	Location	Ground Elevation (m)	Total Depth (m)	Casing Diameter (inch) Pump Housing (Below G.L: m)	Casing Diameter (inch) Screen	S. W. L. (Below G.L m)	Screen Length (m) (Top Level - Bottom Level) (Below G.L: m)	Discharge (l/min) Pumping	Discharge (l/min) Artesian Flowing	Drawdown	Trans-missivity	Storatirity	Remarks
24	K-24/25	Bichwapur		145.0	10 (40.00)	6	2.60	33.00 (53.00-117.00)	343.9		16.93	1.91×10^{-3}		
25	K-26	Imuldihawa		156.0	10 (40.00)	6	A	33.00 (67.50-154.50)	131.9	2.8	27.37	2.20×10^{-2}		
26	K-27/28	Dhandhra		156.0	10 (40.00)	6	3.42	44.00 (51.00-108.50)	330.7		24.88	4.28×10^{-4}		
27	K-29	Dhakeri		156.0	10 (40.00)	6	A	33.00 (41.00-112.00)	133.6	60.1	16.41	8.91×10^{-4}		
28	K-30	Manoharapur		72.5	10 (30.00)	6	A	27.50 (30.00- 71.00)	300.6	300.6	27.80	5.32×10^{-5}		
29	K-31	Naudihawa		162.0	10 (39.00)	6	A	11.00 (44.50- 59.00)	60.1	Drops	25.21	3.82×10^{-5}		
30	K-32/33	Dohani		164.0	10 (31.00)	6	A	28.00 (33.00-158.00)	215.4	19.7	7.95	8.72×10^{-4}		
31	K-34	Barahmasi		87.0	-	6	A	11.00 (58.00- 69.00)	120.2	95.2	-	4.17×10^{-5}		
32	K-35	Madhuban		164.0	10 (30.00)	6	16.26	19.00 (75.00-105.00)	1,202.4		18.00	-		
33	K-36	Darkhaswa		150.5	10 (30.00)	6	6.00	37.50 (30.00-104.50)	2,404.8		8.17	5.95×10^{-2}		
34	K-37	Chapargan		140.0	10 (32.00)	6	2.10	29.00 (32.00-119.00)	2,151.0		19.45	7.33×10^{-3}		
35	K-38	Dhodekoi		132.0	10 (34.00)	6	5.58	28.50 (35.00-114.50)	2,404.8		11.86	1.53×10^{-2}		
36	K-39	Chauwa		131.0	10 (30.00)	6	A	36.50 (30.00-110.50)	-	1,563.1	-	-		

Table B.3 Record of Shallow Tubewells by UNDP (1987)

Well No.		Location	Ground Elevation (m)	Total Depth (m)	Casing Diameter (inch)	S. W. L. (Below G.L m)	Screen Length (m) (Top - Bottom Level Level Below G.L: m)	Discharge (l/min)		Drawdown (m)	Transmissivity (m²/sec)	Storativity	Remarks
								Pumping	Artesian Flowing				
1	STW 1	Amuwa		39.0									* Abandoned.
2	STW 2	Birpur		42.0	4	13.36	5.5 (24.0-29.5)	-					
3	STW 3	Gorusinghe		40.0	4								* Abandoned.
4	STW 4	Simarsat		40.0	4	7.35	5.5 (10.0-15.5)	30.0		0.94	3.70×10^{-4}		
5	STW 5	Bijgauri		50.0	4	5.62	5.5 (13.5-19.0)	600.0		0.30	9.38×10^{-3}		
6	STW 6	Loharaula		44.0	4	3.23	6.0 (13.5-19.5)	720.0		1.72	5.79×10^{-3}		
7	STW 7	Nandnagar		29.0	6	13.02	4.0 (17.5-23.5)	-					
8	STW 8	Bharsarwa		54.0	4	2.27	8.0 (16.0-24.0)	-					
9	STW 9	Dhamaulia		55.0	4	3.13	14.0 (38.0-53.5)	120.0		3.34	3.47×10^{-4}		
10	STW 10	Harnampur		54.0	4	2.14	8.0 (30.5-43.0)	150.0		3.04	6.83×10^{-4}		
11	STW 11	Karmahawa		40.0	4	2.50	5.5 (29.0-34.5)	270.0		2.37	1.76×10^{-3}		
12	STW 12	Auraiha		34.0	4	-	5.5 (25.0-30.5)						
13	STW 13	Sultanpur		62.0	4	4.18	5.5 (54.5-60.0)	84.6		3.71	2.78×10^{-4}		
14	STW 14	Akabarpur		50.0	4	-	5.5 (40.0-45.5)						
15	STW 15	Amuwa		68.0	4	1.80	5.5 (61.0-66.5)	120.0		5.10	3.00×10^{-4}		
16	STW 16	Mahuwa		50.0	4	4.90	5.5 (41.0-46.5)	133.2		2.19	3.82×10^{-4}		
17	STW 18	Baudihawa		40.0	4	3.12	5.5 (28.5-34.0)	15.0		4.06	3.47×10^{-5}		
18	STW 18	Motipur		66.0	4	4.90	6.0 (54.0-63.0)	-					
19	STW 19	Jurpaniya		48.0	4	3.10	5.5 (41.0-46.5)	99.6		3.92	4.17×10^{-4}		
20	STW 20	Kushahawa		56.0	4	-	5.5 (45.5-51.0)						
21	STW 21	Gorushinghe		68.0	4	1.36	16.5 (32.5-60.5)	240.0		4.08	5.32×10^{-4}		
22	STW 22	Bhitriya		36.0	4	2.10	11.0 (23.0-34.0)	120.0		2.91	5.67×10^{-4}		
23	STW 23	Dharampaniya		66.0	4	-	5.5 (59.5-65.0)						

Note: Besides the wells listed in the table there are 17 shallow tubewells installed by HMG/N (Kapilvastu Tubewell Project) in and around Motipur Village situated in the upstream reach of the Banganga. Data of those wells are not available, they say, however that they have obtained an average discharge of 13 l/sec per well.

Table B.4 Chemical Components in Deep Tubewell Water (Artesian Water)

Well No.		Location	Temperature	pH	Electorical Conductivity	Total Solids	Total Alkalinity	Total Hardness	Ca	Mg	Fe	Mn	SiO_2	Cl	SO_4	Ammonia Total	Remarks
			℃		ms/cm	mg/l											
1	OW-1	Sitapur	14.2 (26.1)	7.6 (7.1)	0.65 (0.60)	360	376.2	87.72	26.25	15.85	2.90	0.035	16	11.76	Nil	0.48	
2	PW-1	//	15.0 (26.9)	7.4 (7.4)	0.65 (0.60)	290	396	140.76	26.14	25.77	1.15	0.015	10	9.80	-	0.64	
3	TW-1	Marjadpur (Marchawar)	15.0 (26.2)	7.1 (7.1)	- (0.50)	290	288.4	255.0	49.82	31.71	0.415	0.005	10	7.68	-	0.32	
4	8/3	Mughla	-	8.30	0.445	384	274	156	45	11	-	-	-	9	13	-	
5	8/5	Asnia	-	8.15	0.597	290	358	286	62	32	-	-	-	9	11	-	
6	9/5	Rehara	-	7.90	0.597	302	308	149	17	26	-	-	-	3	12	-	
7	9/8	Motipur	-	7.70	0.653	474	336	295	80	23	-	-	-	8	12	-	
8	10/2	Taulihawa	-	8.80	0.533	360	226	158	32	19	-	-	-	5	7	-	
9	10/5	Gorshingne	-	8.3	0.402	190	238	108	13	18	-	-	-	5	15	-	
10	11/5	Champapur	-	8.3	0.345	128	208	152	19	25	-	-	-	4	11	-	
11	12/5	Dharamnagar	-	7.55	0.633	300	402	301	81	24	-	-	-	6	7	-	
12	13/1	Krishnanagar	-	8.95	0.819	458	342	146	6	32	-	-	-	9	17	-	
13	13/2	Shivanagar	-	8.85	0.751	434	352	153	23	23	-	-	-	7	10	-	

* Well No. 1 to 3 by JICA in this project. Well No. 4 to 13 by USAID.

* ( ) measured in the field.

Table B.5 Static Water Level of Dugwells in Kapilvastu and Marchawar

STATIC WATER LEVEL OF DUGWELLS IN KAPILVASTU

Well No.		Location	S. W. L (Below G.L: m)							
			1987	1988						
			Nov.	Jan.	Mar.	May	Jun.	Jul.	Aug.	Oct.
1	KD- 1	Dohani	2.20	2.20	2.41	2.82	3.90	△ 4.50	2.20	○ 1.31
2	KD- 2	Tulripur	2.00	2.22	2.35	2.95	2.90	△ 3.00	1.98	○ 0.88
3	KD- 3	Hardewa	2.30	2.80	3.15	△ 3.60	2.50	2.95	1.05	○ 0.83
4	KD- 4	Harnampur	1.80	2.00	2.29	2.80	3.70	△ 3.75	1.95	○ 1.00
5	KD- 5	Kajarahawa	3.00	3.20	3.42	△ 4.20	3.60	4.00	2.95	○ 2.00
6	KD- 6	Gulta	1.40	1.75	2.00	△ 3.20	1.05	2.00	1.00	○ 0.75
7	KD- 7	Shirsihawa	3.50	4.35	4.50	5.00	5.45	△ 6.00	4.00	○ 2.10
8	KD- 8	Ganeshpur	1.90	2.20	2.41	3.10	3.35	△ 3.40	1.90	○ 1.30
9	KD- 9	Itraula	3.00	3.26	3.50	3.80	3.80	△ 4.15	3.00	○ 1.75
10	KD-10	Gairahawa	○ 1.50	1.70	2.00	3.00	3.35	△ 4.10	2.90	1.95
11	KD-11	Dhankauli	3.00	4.20	4.30	3.20	4.40	△ 4.70	3.00	○ 1.16
12	KD-12	Phulika	2.00	2.10	2.10	3.30	2.90	△ 3.35	2.00	○ 0.96
13	KD-13	Bhalui	1.60	2.00	△ 2.30	△ 2.30	1.95	2.10	1.00	○ 0.90
14	KD-14	Jagdishpur	○ 0.55	2.90	3.00	△ 3.50	3.20	3.00	1.95	1.30
15	KD-15	Sitapur	○ 1.00	2.20	2.51	3.00	3.95	△ 4.50	2.86	1.30
16	KD-16	Chanai	○ 1.30	1.50	2.15	3.10	6.15	△ 6.45	4.00	2.05
17	KD-17	Thankhajni	1.94	2.05	2.25	3.00	△ 3.65	3.50	2.15	○ 1.00
18	KD-18	Loharaula	△ 4.00	2.20	2.35	3.20	3.25	3.85	2.10	○ 1.20
19	KD-19	Chhoti Bhagwanpur	4.00	4.20	4.40	4.60	5.50	△ 6.20	4.20	○ 2.20
20	KD-20	Dhanchaura	2.00	2.15	2.35	3.20	3.80	△ 4.00	2.98	○ 1.30
21	KD-21	Motipur	○ 1.20	2.00	2.40	3.20	3.30	△ 4.00	1.90	1.70
22	KD-22	Tenuwa	1.80	2.10	2.30	△ 5.60	2.00	2.10	○ 1.10	○ 1.10
23	KD-23	Jinuwa	1.80	2.05	2.90	3.40	3.03	△ 3.60	2.00	○ 1.50
24	KD-24	Gandehawa	○ 1.50	3.60	3.80	△ Dry	4.30	△ 4.35	3.00	2.75
25	KD-25	Birpur	3.50	4.30	8.20	△ Dry	△10.30	△ Dry	1.05	○ 1.00
26	KD-26	Ramuwadhawa	3.85	4.00	4.30	4.70	5.15	△ 5.30	4.00	○ 1.60

○: Highest Level, △: Lowest Level

STATIC WATER LEVEL OF DUGWELLS IN MARCHAWAR

(Estimated by hearing)

Well No.		Location	Well Depth (m)	S. W. L (Below G.L :m)	
				Highest	Lowest
1	MD- 1	Sheopur	4.90	0.75	2.40
2	MD- 2	Parsahwa	5.00	0.50	4.50
3	MD- 3	Sisu Seinraha	5.45	1.40	4.00
4	MD- 4	Dayanagar	5.46	1.00	4.00
5	MD- 5	Kadmahwa	7.65	1.65	5.24
6	MD- 6	Phuiwaria	5.00	1.00	3.62
7	MD- 7	Dhaulia	5.74	0.70	4.50

Table B.6 Chemical Components in Dugwell and Handpump Water

Well No.		Location	Temperature	pH	Total Solids	Total Alkalinity	Total Hardness	Ca	Mg	Fe	Mn	SiO_2	Cl	SO_4	Ammonia Total	Remarks
			℃		mg/l											
1	KD-6	Gulta	14	7.9	676	352.44	510.00	124.97	48.06	0.01	0.005	1.2	384.0	Nil	0.1	
2	KD-9	Itraula	14	7.3	247	362.34	489.6	71.88	75.32	0.01	0.005	4.0	19.2	Nil	0.2	
3	(KD-14)	Jagdishpur	14	7.8	663	611.82	275.4	28.59	49.55	0.23	0.07	4.0	48.0	Nil	0.02	* Sample was taken from handpump well near KD-14
4	(KD-19)	Pahatkaul	14	7.7	997	437.58	326.4	93.93	22.29	0.01	0.07	6.0	134.4	Nil	0.05	* Sample was taken from dugwell near KD-19.
5	(KD-20)	Barkulpur	14	7.0	829	475.00	489.6	105.37	55.0	0.01	0.09	4.0	115.2	Nil	0.1	* Sample was taken from dugwell near KD-20.
6	(KD-25)	Birpur	14	7.5	176	25.74	220.32	55.54	19.82	0.01	0.01	4.0	19.2	Nil	0.04	* Sample was taken from dugwell near KD-25.
7	MD-6	Phulwaria (Marchawar)	14	7.5	680	459.36	367.2	63.71	50.54	0.01	0.005	6.0	124.8	Nil	0.04	
8	KS-1	Shivapur	14	7.2	223	314.82	273.36	51.46	35.18	0.01	0.005	4.0	19.2	Nil	0.02	* Sample was taken from natural spring near KD-26.

Table B.7 Results of Study on Possibility of Groundwater Exploitation

Potential Area / Type of Well	High ($T^{135} = 3.74 \times 10^{-2}$ m²/sec)			Moderate ($T^{135} = 3.94 \times 10^{-3}$ m²/sec)			Low ($T^{135} = 4.01 \times 10^{-4}$ m²/sec)			Remarks
Deep (Depth: 200 m, Diameter: 8")	$T^{200} = 6.4 \times 10^{-2}$ m²/sec, $S^{DH} = 5.0 \times 10^{-3}$			$T^{200} = 6.7 \times 10^{-3}$ m²/sec, $S^{DM} = 5.0 \times 10^{-4}$			$T^{200} = 6.9 \times 10^{-4}$ m²/sec, $S^{DL} = 5.0 \times 10^{-5}$			Pumping hour: 12 hrs/day
	Discharge (l/sec)	50	40	Discharge (l/sec)	50	40	Discharge (l/sec)	25	10	
	Drawdown (m)	1.12	0.90	Drawdown (m)	10.7	8.55	Drawdown (m)	51.9	20.8	
	Radius of Influence (m)	900	900	Radius of Influence (m)	900	900	Radius of Influence (m)	900	900	
Shallow (Depth: 70 m, Diameter: 8")	$T^{70} = 1.1 \times 10^{-2}$ m²/sec, $S^{SH} = 1.0 \times 10^{-3}$			$T^{70} = 1.2 \times 10^{-3}$ m²/sec, $S^{SM} = 1.0 \times 10^{-4}$			$T^{70} = 1.2 \times 10^{-4}$ m²/sec, $S^{SL} = 1.0 \times 10^{-5}$			Pumping hour: 12 hrs/day
	Discharge (l/sec)	50	40	Discharge (l/sec)	15	10	Discharge (l/sec)	10	5	
	Drawdown (m)	6.51	5.21	Drawdown (m)	17.9	11.9	Drawdown (m)	119.4	59.7	
	Radius of Influence (m)	900	900	Radius of Influence (m)	900	800	Radius of Influence (m)	900	900	
Hand Pump (Depth: 30 m, Diameter: 4")				$T = 1.0 \times 10^{-6}$ m²/sec, S (Effective Porosity) = 0.25						Pumping hour: 12 hrs/day
				Discharge (l/sec)	1.0	0.2				
				Drawdown (m)	59.7	11.9				
				Radius of Influence (m)	22	90				
Remarks	Discharge of more than 50 l/sec could be obtained from both a deep and a shallow tubewell in high potential area. In this case, however, larger diameter well will be required.						Low potential area is not suitable for deep and shallow tubewell.			

Table B.8 Number of Wells and Prospective Quantity of Water

		Pumping (l/sec / hrs. cycle)	Area (km²)	Radius of Influence (km)	Influence Area (km²)	Well Number to be Constructed (nos.)	Existing Well (nos.)	Proposed Well Number (nos.)	Proposed Discharge (m³/day)	Total Discharge (m³/day)	Remarks
High Potential Area	North Banganga R. Area	50 / 12	30.6	0.9	2.54	12	4	8	17,000+	25,000+	
		50 / 12		0.9	2.54	12		8	17,000+	25,000+	
Moderate Potential Area	South Banganga R. Area	50 / 12	19.4	0.9	2.54	7	19	-	-	15,000	* There is no space for proposed well. * Total discharge is calculated with 7 deep tubewells and 9 shallow tubewells respectively.
		10 / 12		0.8	2.01	9		-	-	3,000	
	Western Area	50 / 12	40.0	0.9	2.54	15	7	8	17,000	30,000	
		10 / 12		0.8	2.01	19		12	5,000	8,000	
	South-Western Area (Krishnanagar Area)	50 / 12	29.2	0.9	2.54	11	5	6	12,000	20,000	
		10 / 12		0.8	2.01	14		9	3,000	6,000	
	Marchawar Area	50 / 12	22.8	0.9	2.54	8	1	7	15,000	17,000	* Area is only inside the study area.
		10 / 12		0.8	2.01	11		10	4,000	4,000	
Low Potential Area	Remained Area	Hand Pump					67+				
Total						53	103+	29	61,000+	107,000+	
						65		39	29,000+	46,000+	

Note: 1) "Existing Well" includes both deep and shallow tubewells.

2) In "High Potential Area", "Moderate Potential Area" and "Total" columns, a case of deep tubewell is indicated in upper part and a case of shallow tubewell is in lower part respectively.

3) In "Proposed Discharge" and "Total Discharge" columns, any fractional sum less than 1,000 m³/day discharge shall be discarded.

4) Existing wells are assumed to be arranged and pumped as proposed wells.

FIGURES

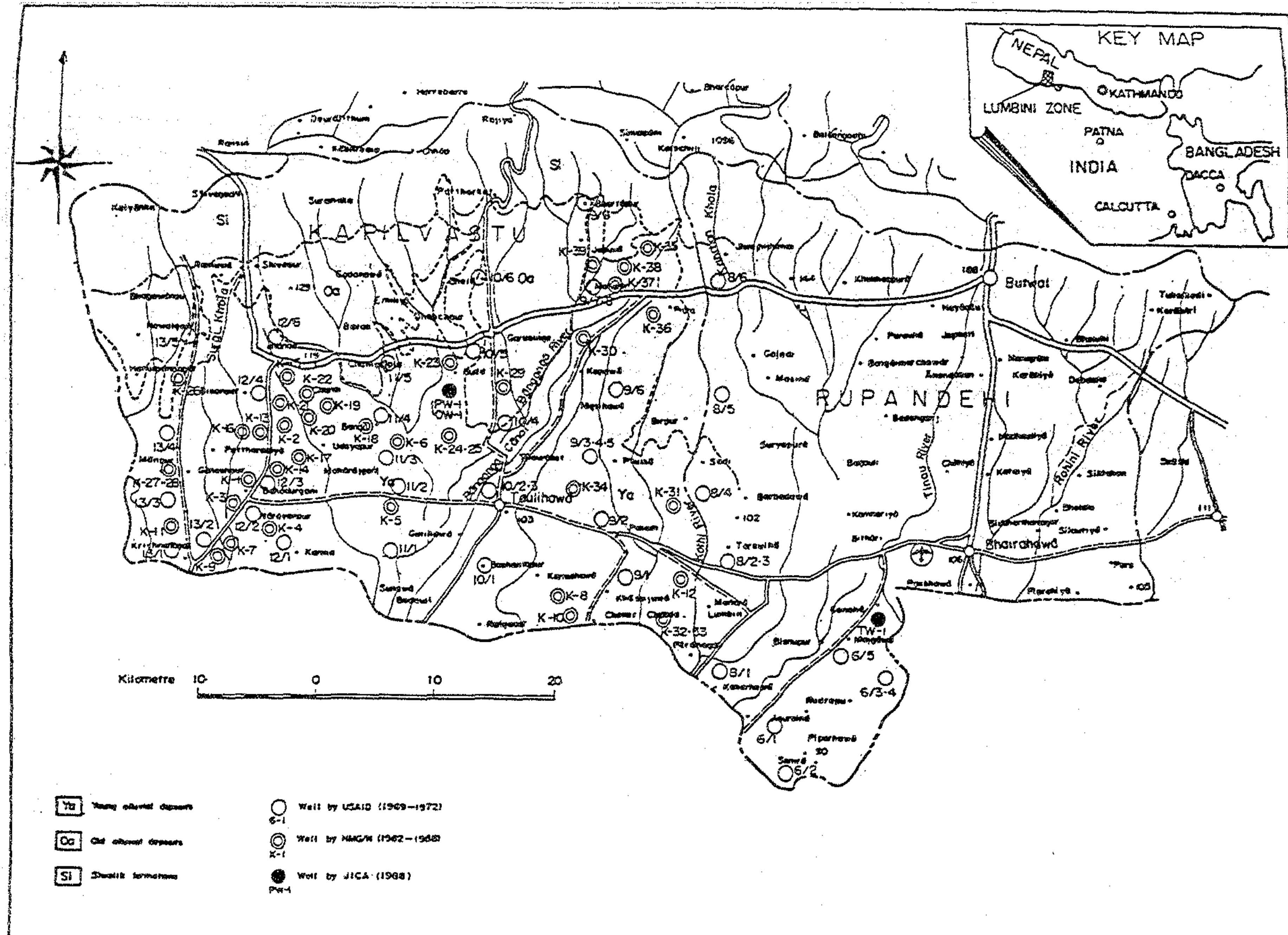


Fig. B.1 Location Map of Deep Tubewell

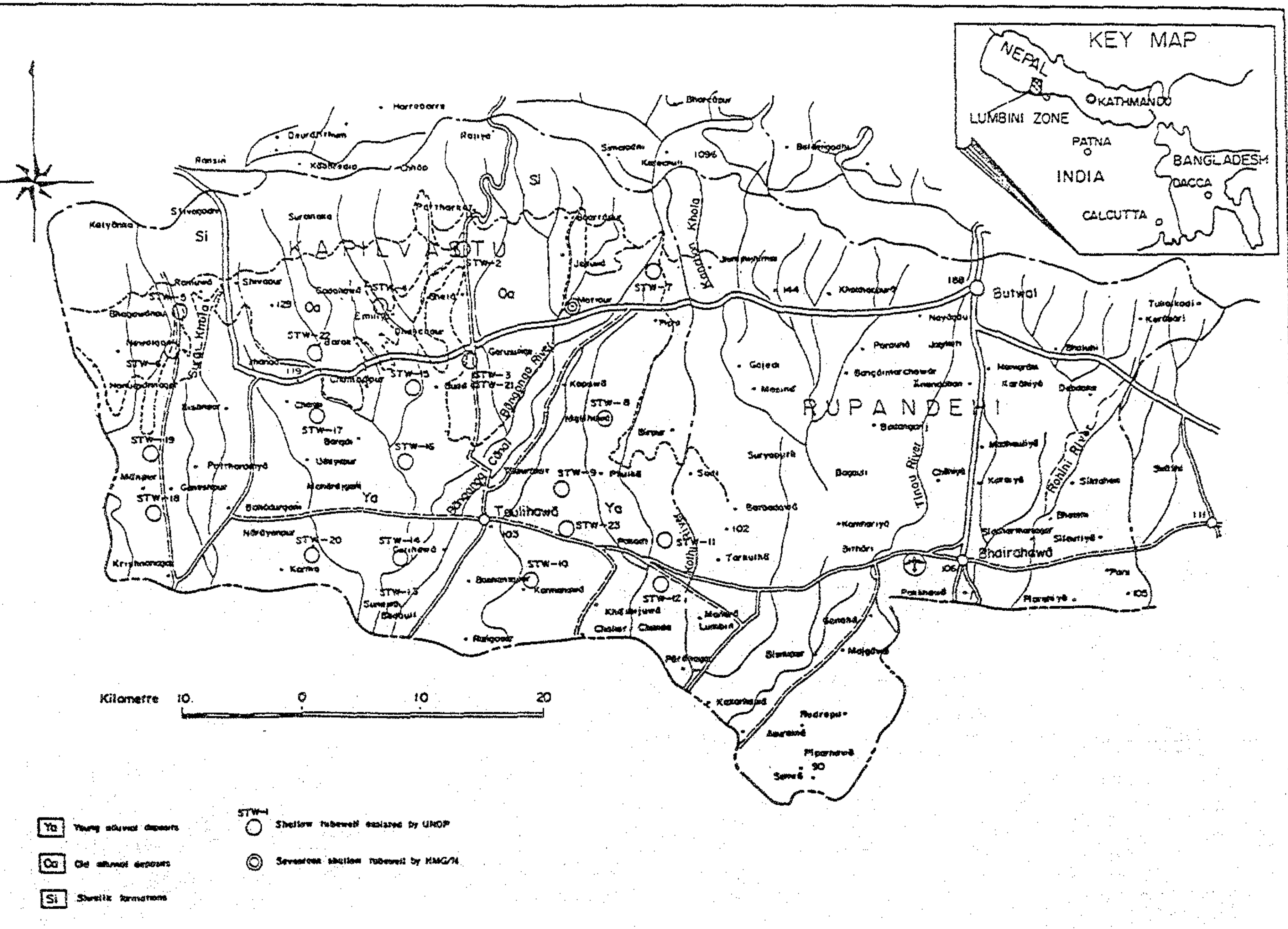


Fig. B.2 Location Map of Shallow Tubewell

Fig. B.3.1 Location Map (PW-1 & OW-1)

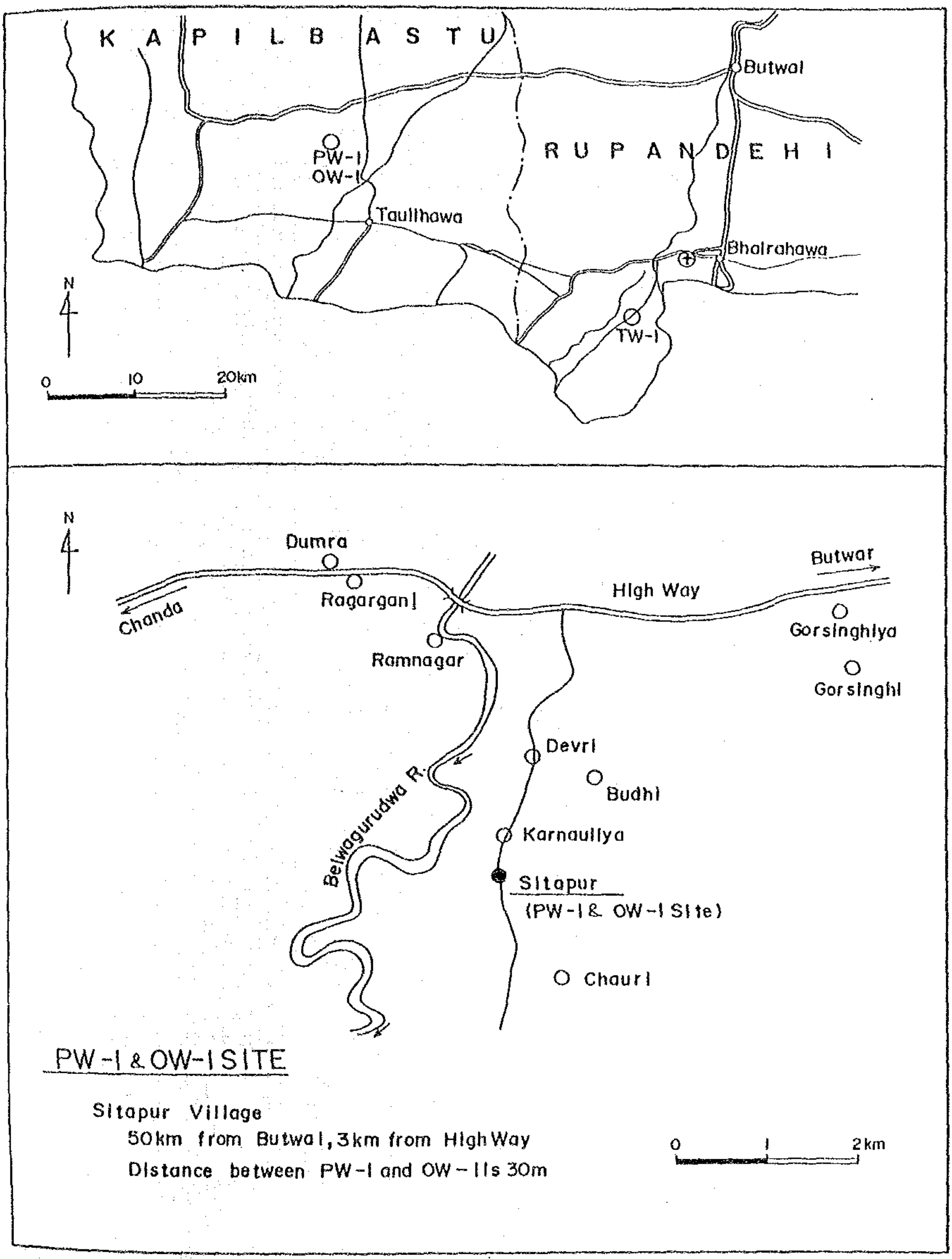
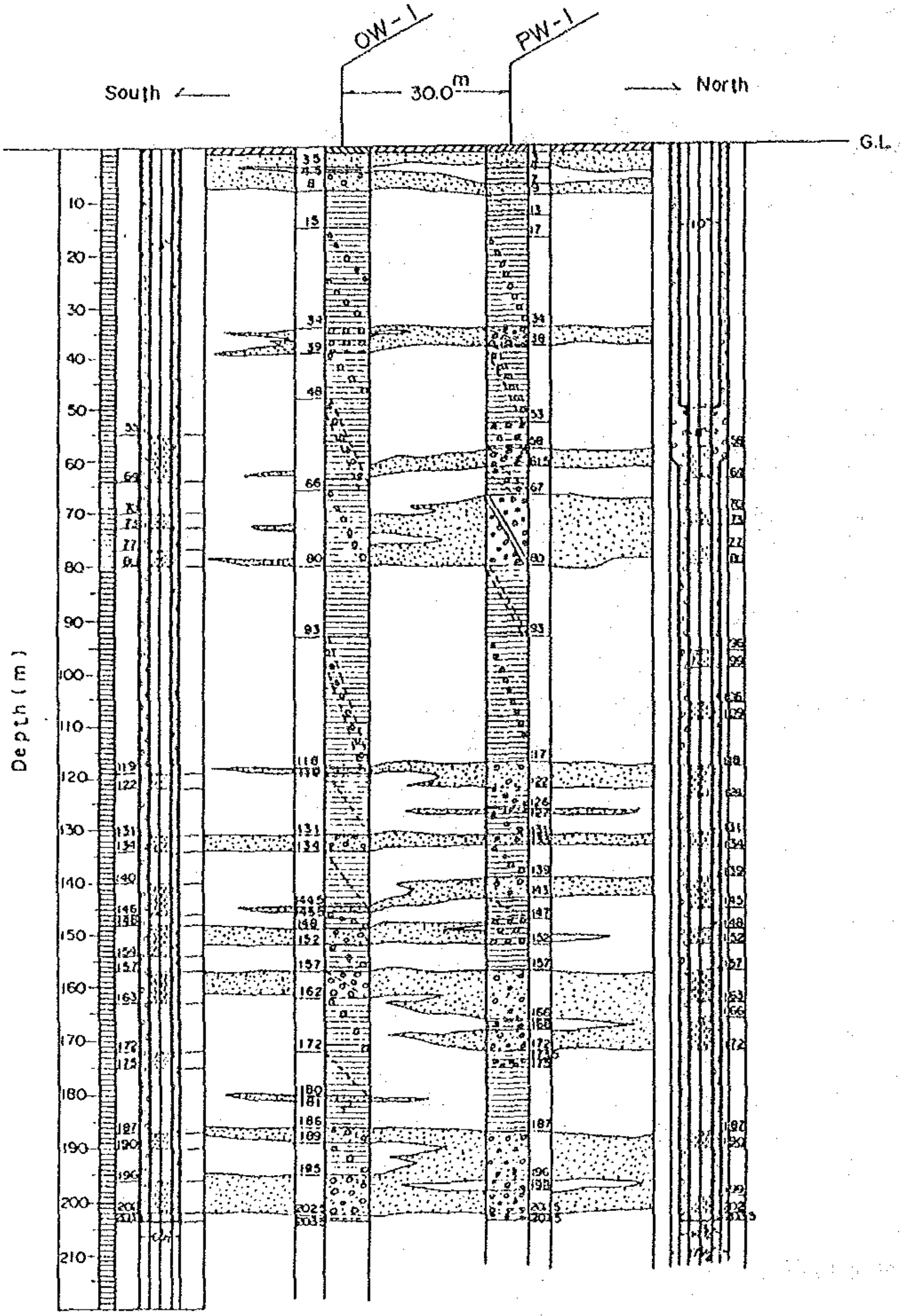


Fig. B.3.2 Geological Profile

OW-1 — PW-1



LEGEND

Top soil Sandy layer Clayey layer

Fig. B.3.3 Well Log (PW-1)

PROJECT NAME	THE INTEGRATED RURAL DEVELOPMENT PROJECT IN THE LUMBINI ZONE	WELL NO	PW-1
AREA AND LOCATION	KAPILVASTU, LUMBINI ZONE		
ELEVATION	m	LATITUDE	LONGITUDE
TOTAL DEPTH	G.L- 203.5 m	DRILLING RIG	TBM-70 ROTARY TYPE
DRILLING STARTED	25 DECEMBER 1988	DRILLED BY	A.B. SHRESTHA
WELL COMPLETED	30 JANUARY 1989	LOGGED BY	R. GAUTAM

STATIC WATER LEVEL	G.L+0.20m	WATER TEMPERATURE	26.9 ℃
DYNAMIC WATER LEVEL	GL-39.05 m	CONDUCTIVITY	0.6 μu/cm
PUMPING RATE	2339 ℓ/min (337 m³/d)	pH	7.4
SPECIFIC CAPACITY	8.6 m³/d/m	TOTAL HARDNESS	140.76

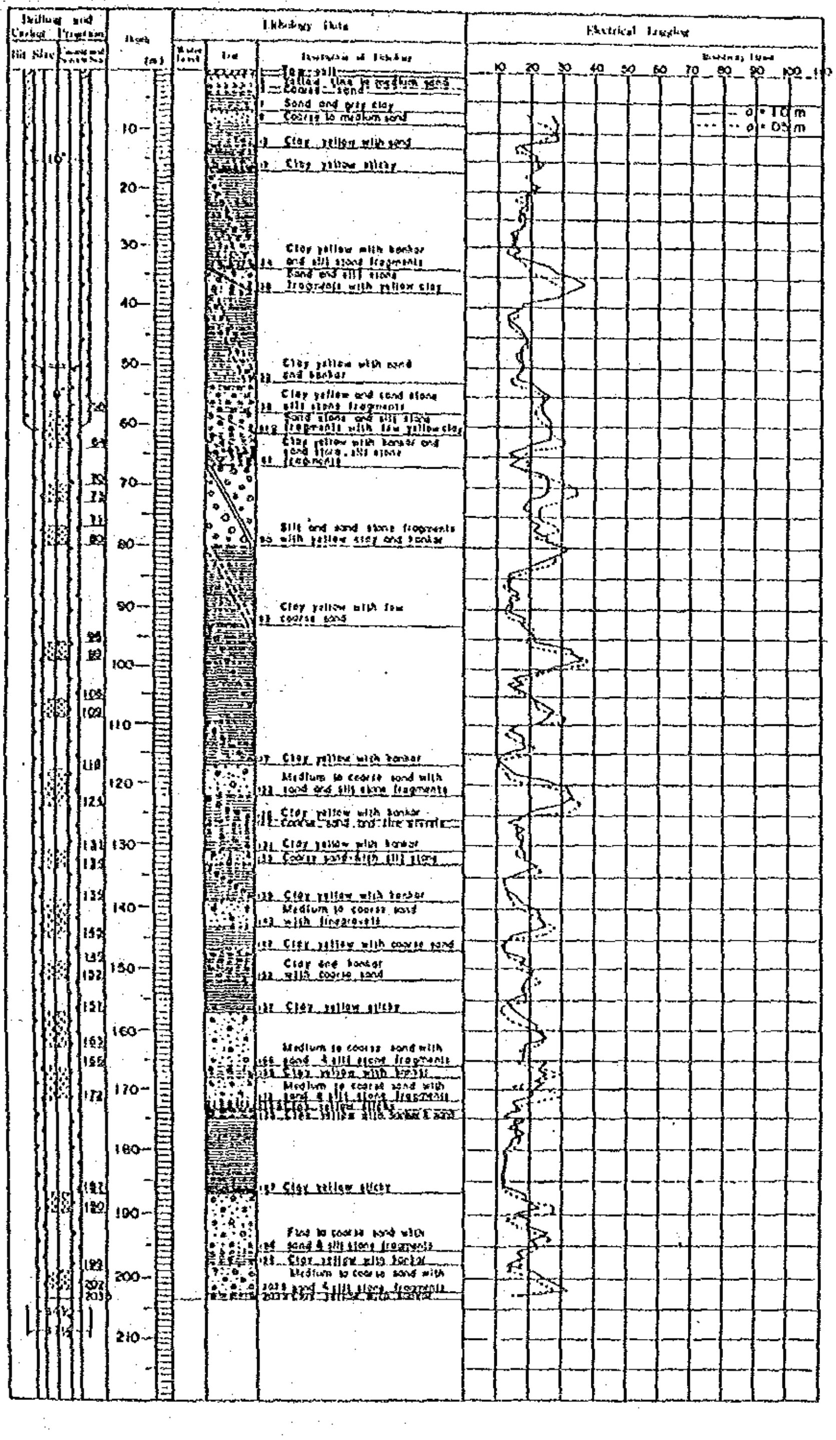
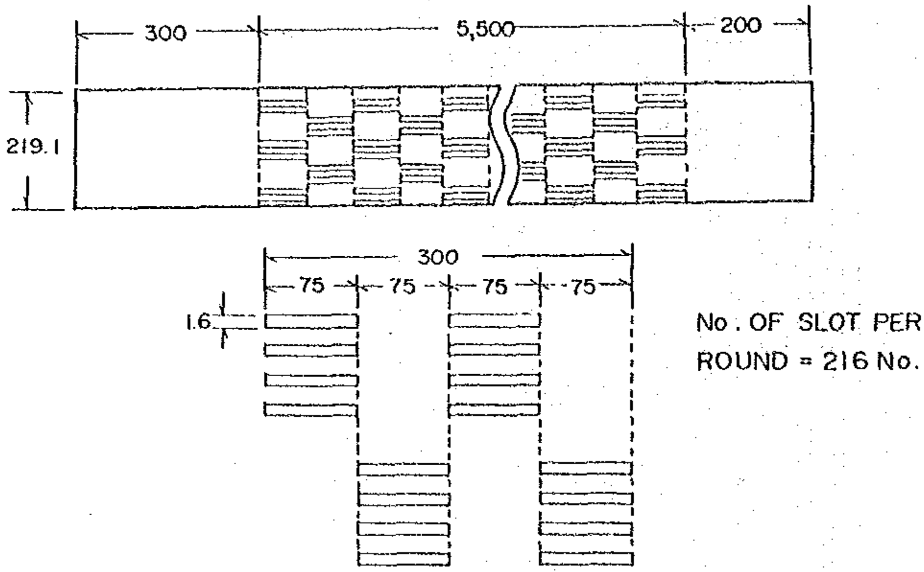


Fig. B.3.4 Opening Ratio of Slotted Screen Pipe and Chemical Components (PW-1)

8" SLOTTED SCREEN PIPE

UNIT : mm



SURFACE AREA $A = \pi DL = 3.14 \times 219.1 \times 300 = 206{,}392\ mm^2$

OPENING AREA $A' = 1.6 \times 75 \times 216 = 25{,}920\ mm^2$

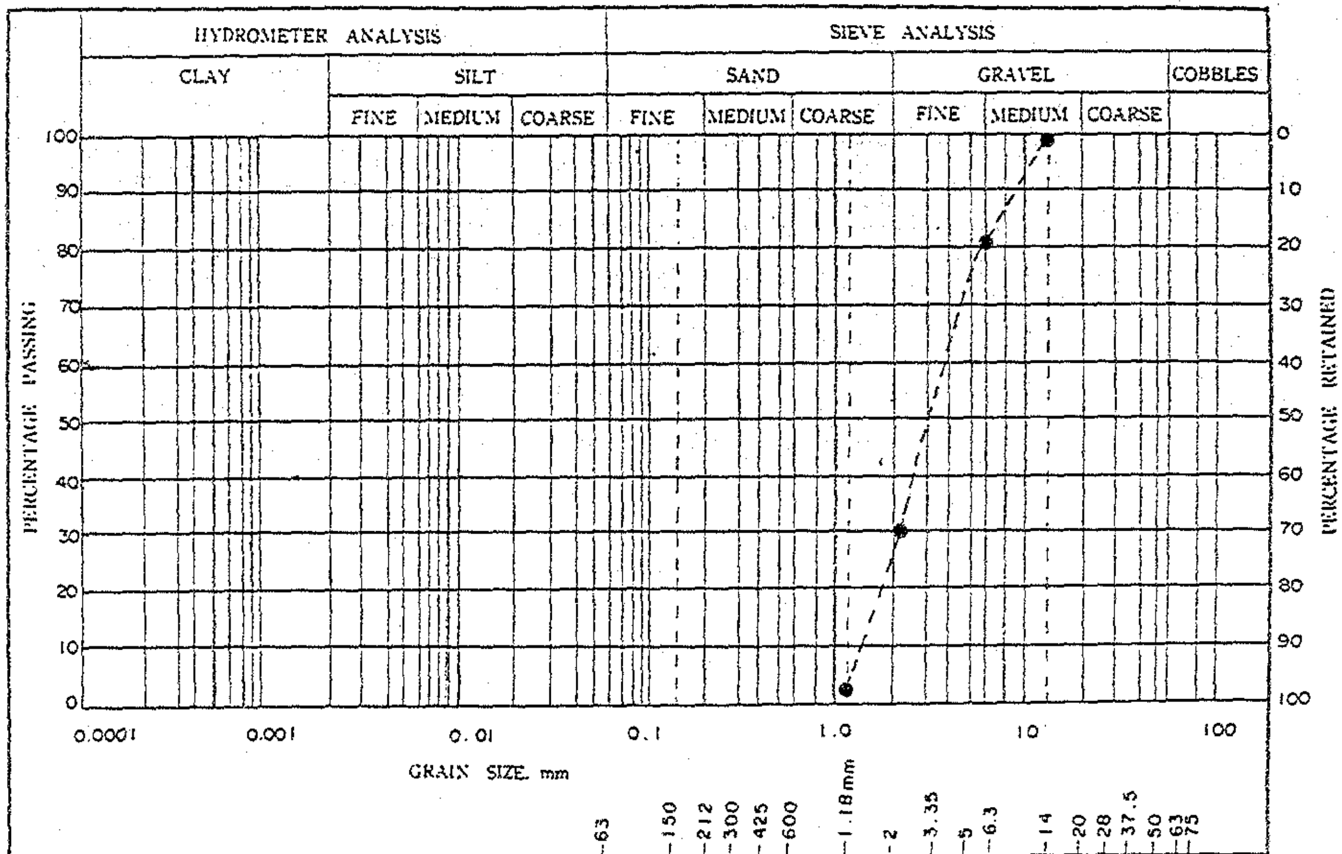
OPENING RATIO $A'/A \times 100\% = \underline{12.6\%}$

CHEMICAL COMPONENTS

Temperature	°C	15.0 (26.9)	Ca	mg/ℓ	26.14
pH		7.4 (7.4)	Mg	mg/ℓ	25.77
Electrical Conductivity	ms/cm	0.65 (0.6)	Fe	mg/ℓ	1.15
Total Solids	mg/ℓ	290	Mn	mg/ℓ	0.015
Total Alkalinity	mg/ℓ	396	SiO_2	mg/ℓ	10
Total Hardness	mg/ℓ	140.76	Cl	mg/ℓ	9.8
Ammonia Total	mg/ℓ	0.64	SO_4	mg/ℓ	—

( ) measured in the field

Fig. B.3.5 Gradation Curve for Gravel Pack Material (PW-1)



SYMBOL	BORE HOLE	DEPTH m.	DESCRIPTION OF SOILS	d_{60}	d_{10}	u	REMARKS
			Medium to fine gravel	3.9	1.5	2.6	

22nd-24th Jan.1989

Fig. B.3.6 Step Drawdown Test (1)

Water Level-Time Curve

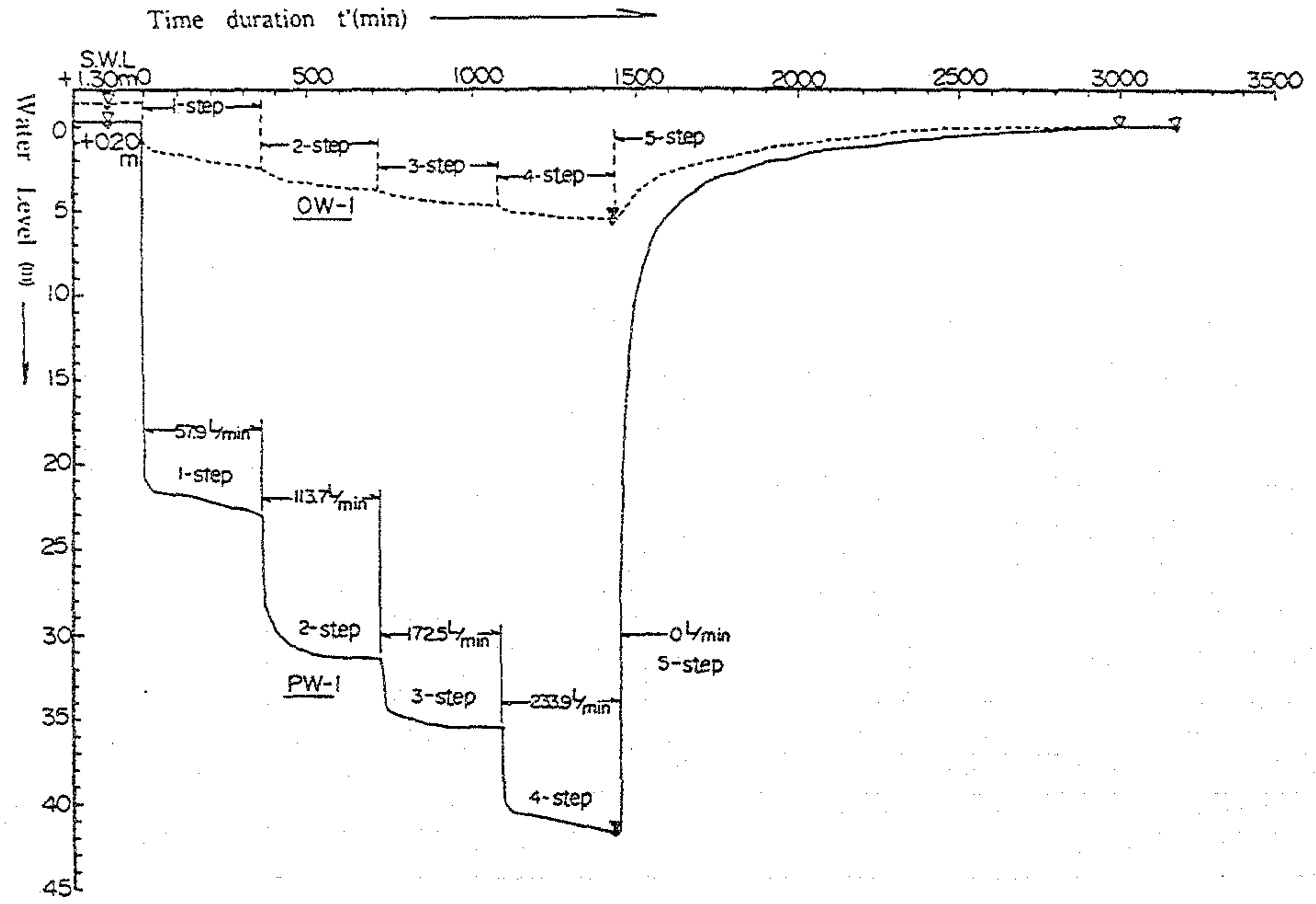
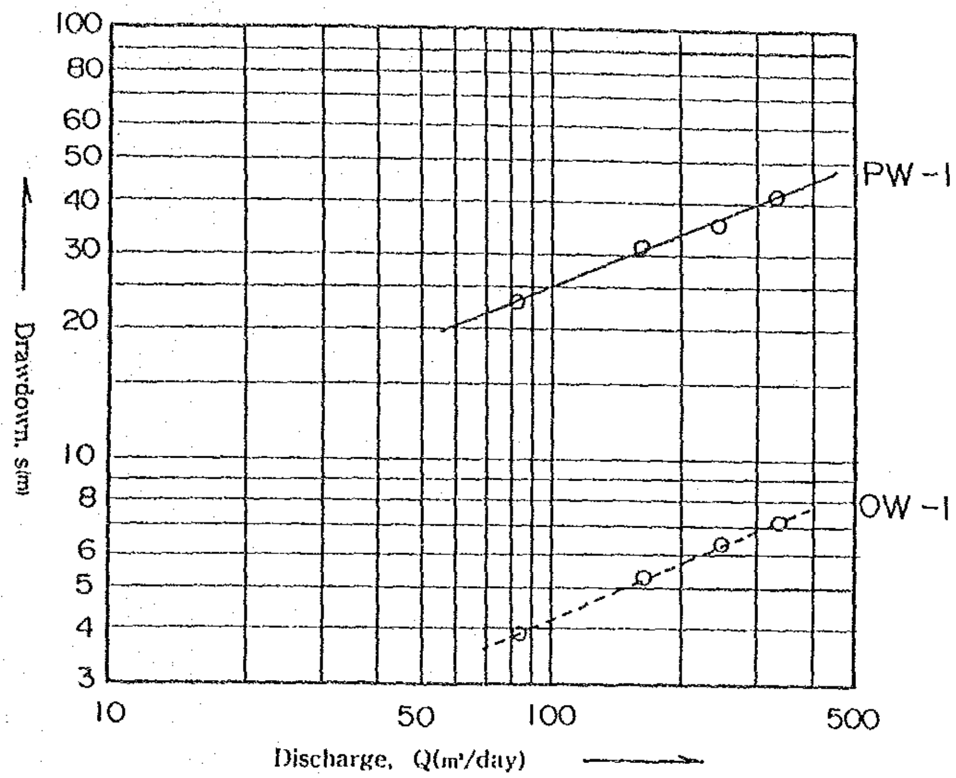


Fig. B.3.7 Step Drawdown Test (2)

Q~s Curve



Specific Cabacity (PW-1)

Step	Discharge Q(m^3/d)	D.W.L (m)	Drawdown s (m)	Specific Capacity Q/s (m^3/d/m)
1	83.4	23.06	23.26	3.59
2	163.7	31.41	31.61	5.18
3	248.4	35.57	35.77	6.94
4	336.8	41.66	41.86	8.05

Note : Static Water level (S.W.L) = + 0.20 m

24th-28th.Jan.1989

Fig. B.3.8 Cotinuous Test (PW-1)

Water Level-Time Curve

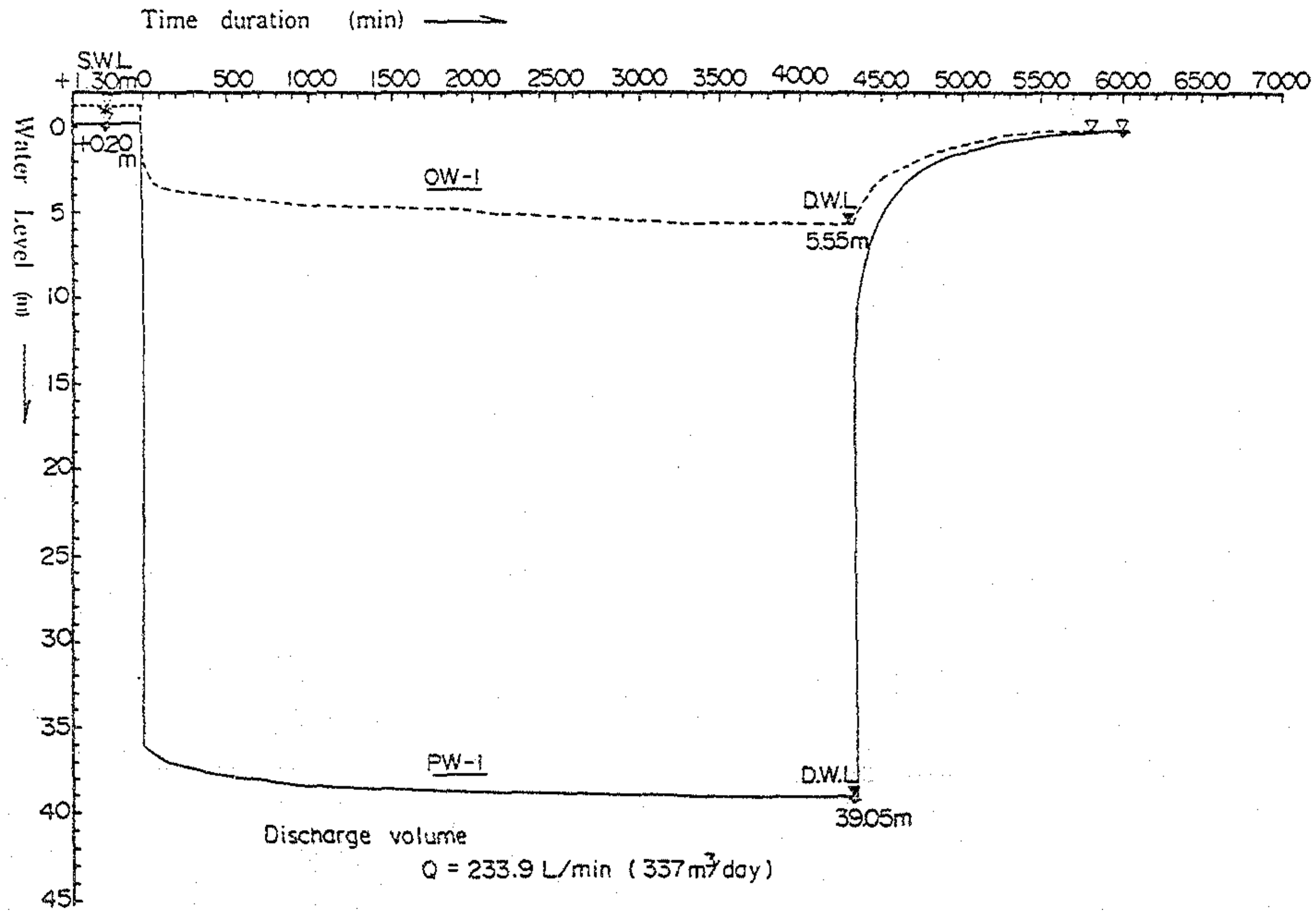


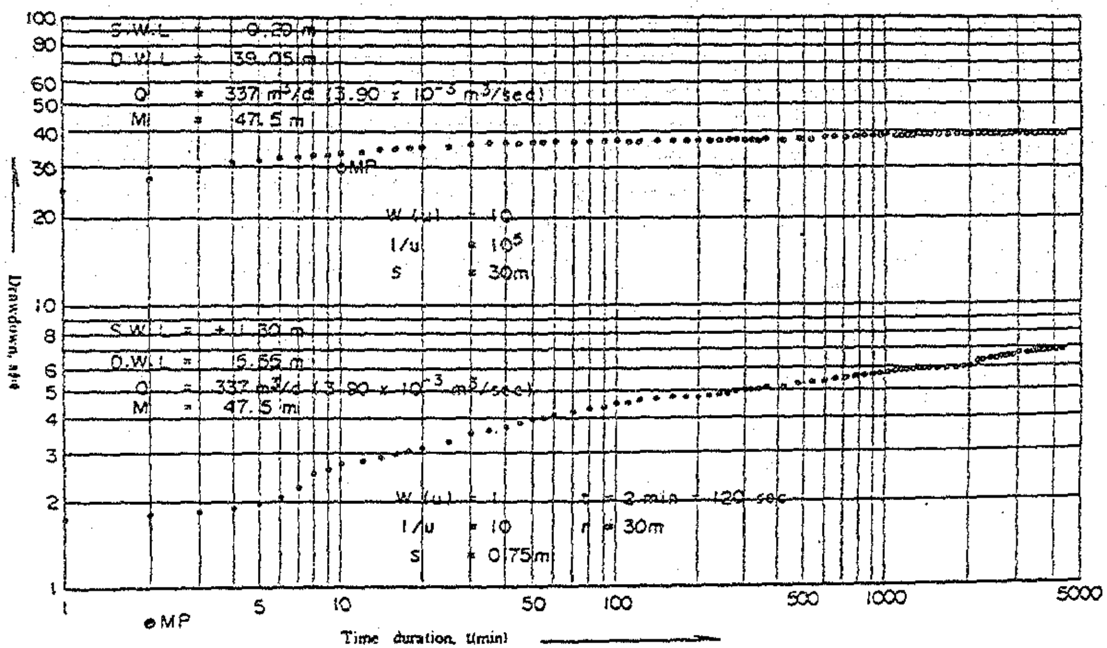
Fig. B.3.9 Aquifer Test (Continuous Test)(PW-1,OW-1)

Continuous Test

t~s Curve

$$T = \frac{0.0796\,Q}{s} W(u) = \frac{0.0796 \times 3.90 \times 10^{-3}}{30} \times 10 = 1.03 \times 10^{-4}\ m^2/sec$$

$$k = \frac{T}{M} = \frac{1.03 \times 10^{-4}}{47.5} = 2.17 \times 10^{-6}\ m/sec = 2.17 \times 10^{-4}\ cm/sec$$



$$T = \frac{0.0796\,Q}{s} W(u) = \frac{0.0796 \times 3.90 \times 10^{-3}}{0.75} \times 1 = 4.14 \times 10^{-4}\ m^3/sec$$

$$k = \frac{T}{M} = \frac{4.14 \times 10^{-4}}{47.5} = 8.72 \times 10^{-6}\ m/sec = 8.72 \times 10^{-4}\ cm/sec$$

$$S = \frac{4T\,t}{r^2(1/u)} = \frac{4 \times 4.14 \times 10^{-4} \times 120}{30^2 \times 10} = 2.21 \times 10^{-5}$$

OW-1 : AQUIFER TEST (Theis Method of the Analysis)

Continuous Test

t ~ s curve

Fig. B.3.10 Well Log (OW-1)

PROJECT NAME THE INTEGRATED RURAL DEVELOPMENT PROJECT IN THE LUMBINI ZONE	WELL NO OW-1
AREA AND LOCATION KAPILVASTU, LUMBINI ZONE	
ELEVATION m	LATITUDE LONGITUDE
TOTAL DEPTH GL-203.5 m	DRILLING RIG TBM-70 ROTARY TYPE
DRILLING STARTED 26 NOVEMBER 1988	DRILLED BY A.B. SHRESTHA
WELL COMPLETED 24 DECEMBER 1988	LOGGED BY R. GAUTAM

STATIC WATER LEVEL	G.L+1.30m	WATER TEMPERATURE	26.1°C
DYNAMIC WATER LEVEL	G.L-20.27m	CONDUCTIVITY	0.6 µΩ/cm
PUMPING RATE	234 ℓ/min (337 m³/d)	pH	7.1
SPECIFIC CAPACITY	11.4m³/d/m	TOTAL HARDNESS	87.72

ARTESIAN FLOW 12 ℓ/min

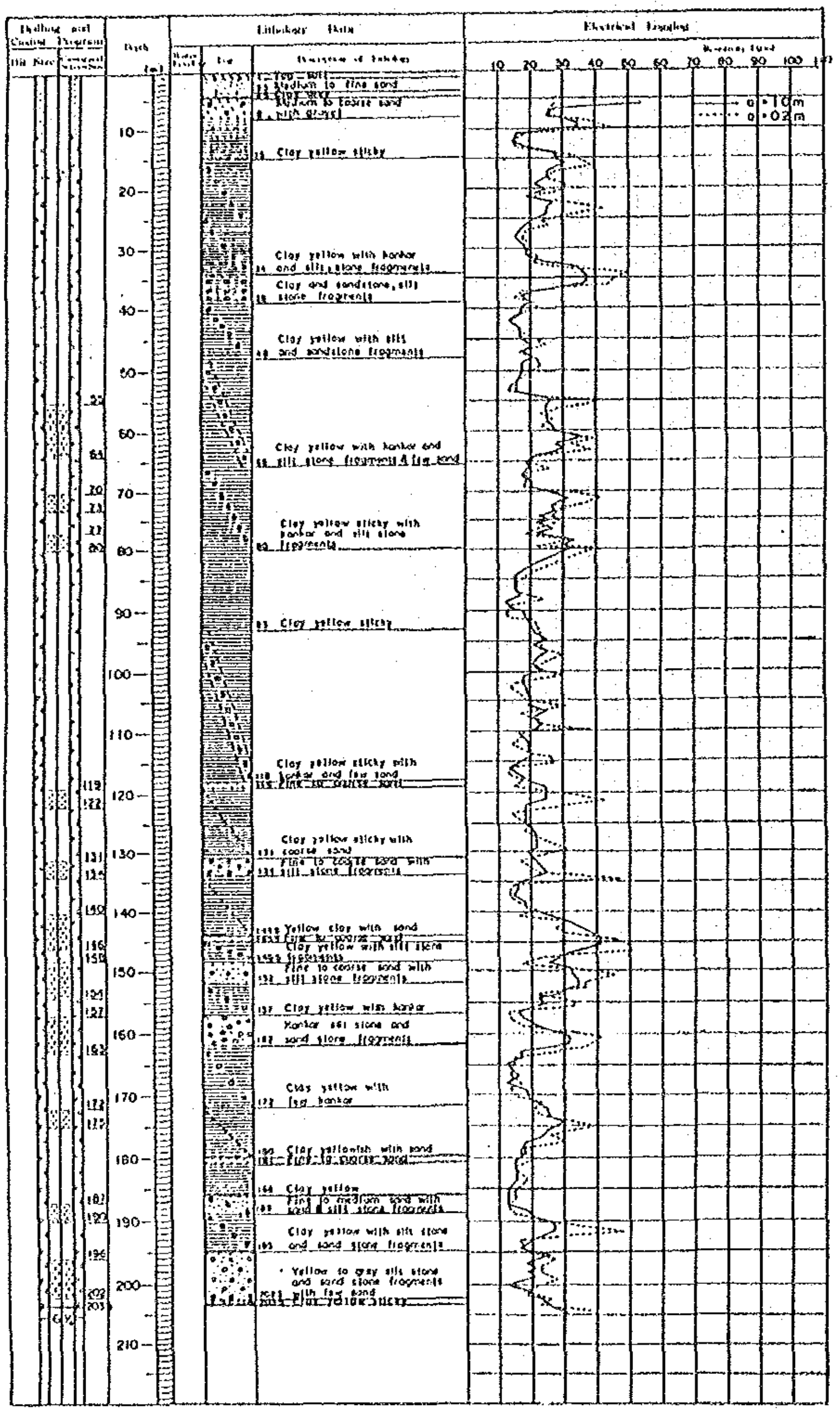
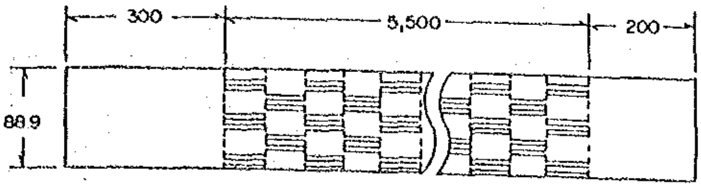
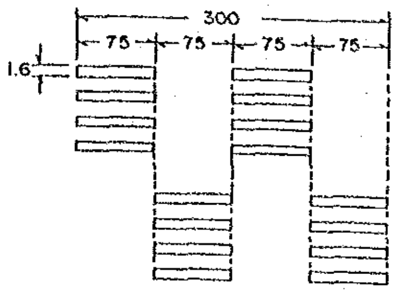


Fig. B.3.11 Opening Ratio of Slotted Screen Pipe and Chemical Components (OW-1)

3" SLOTTED SCREEN PIPE

UNIT : mm





No. OF SLOT PER ROUND = 84 No.

SURFACE AREA $A = \pi D L = 3.14 \times 88.9 \times 300 = 83{,}743\ mm^2$

OPENING AREA $A' = 1.6 \times 75 \times 84 = 10{,}080\ mm^2$

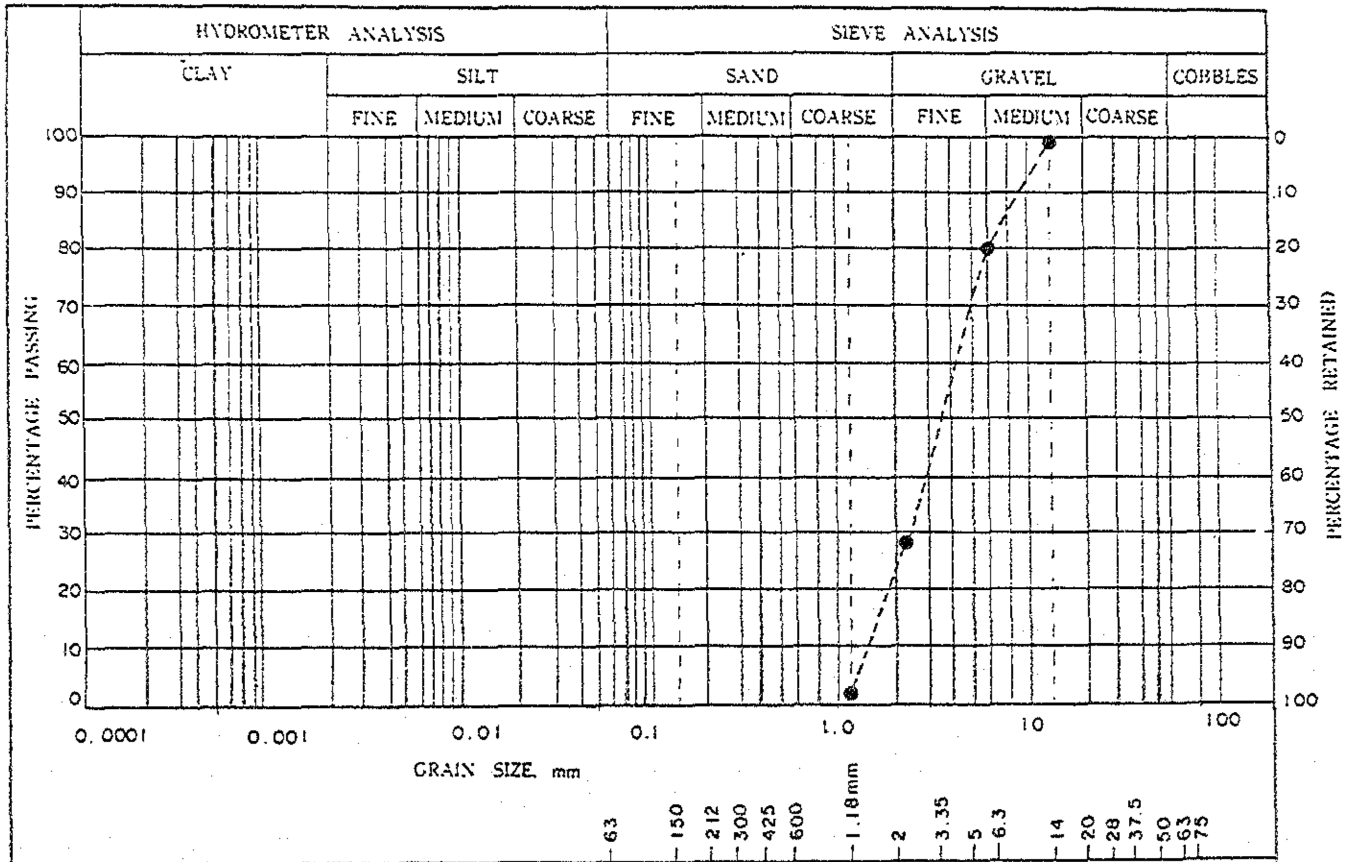
OPENING RATIO $A'/A \times 100\% = \underline{12.0\%}$

CHEMICAL COMPONENTS

Temperature	℃	14.2 (26.1)	Ca	mg/ℓ	26.25
pH		7.1 (7.1)	Mg	mg/ℓ	15.85
Electrical Conductivity	ms/cm	0.65 (0.6)	Fe	mg/ℓ	2.90
Total Solids	mg/ℓ	360	Mn	mg/ℓ	0.035
Total Alkalinity	mg/ℓ	376.2	SiO_2	mg/ℓ	16
Total Hardness	mg/ℓ	87.72	Cl	mg/ℓ	11.76
Ammonia Total	mg/ℓ	0.48	SO_4	mg/ℓ	Nil

( ) measured in the field

Fig. B.3.12 Gradation Curve for Gravel Pack Materials (OW-1)

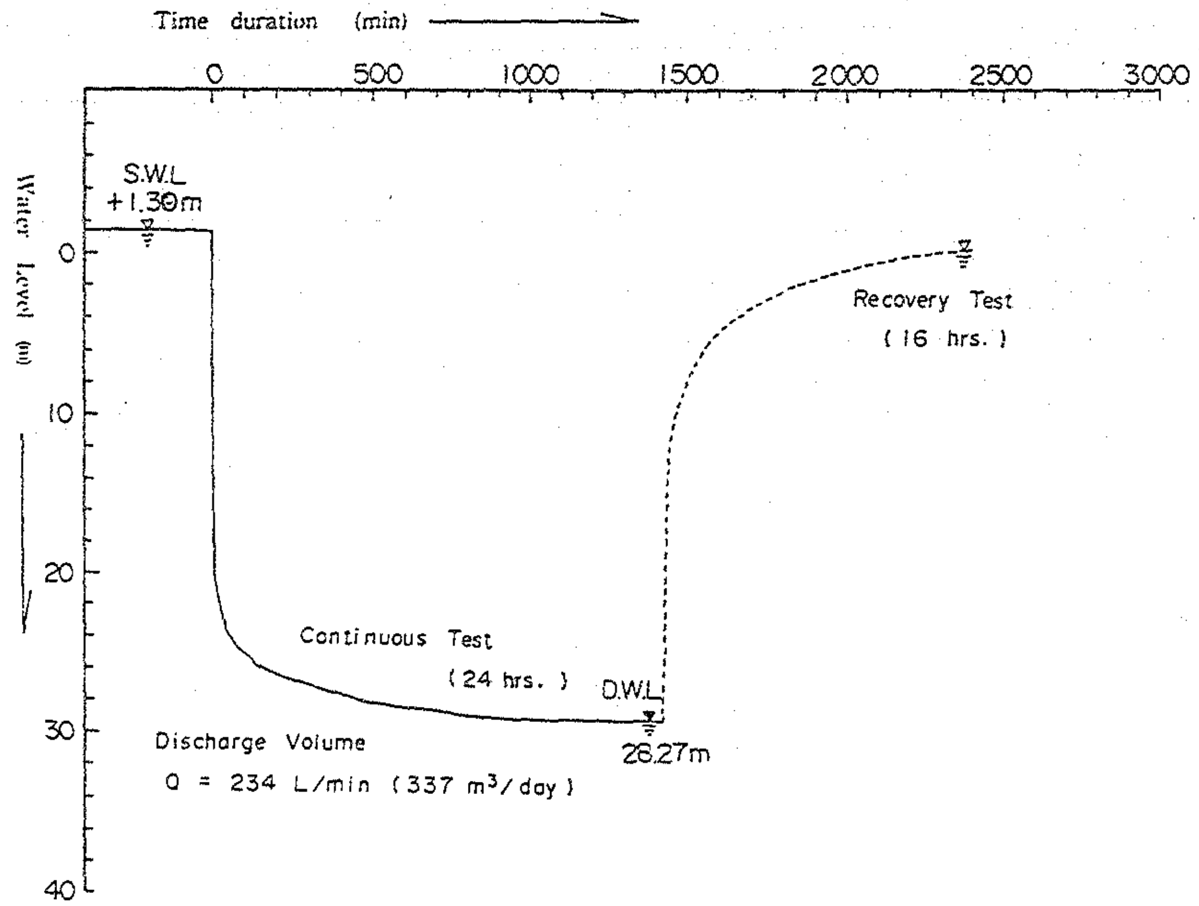


SYMBOL	BORE HOLE	DEPTH m.	DESCRIPTION OF SOILS	d_{60}	d_{10}	u	REMARKS
			Medium to fine gravel	4.0	1.6	2.5	

22nd−23rd Dec.1988

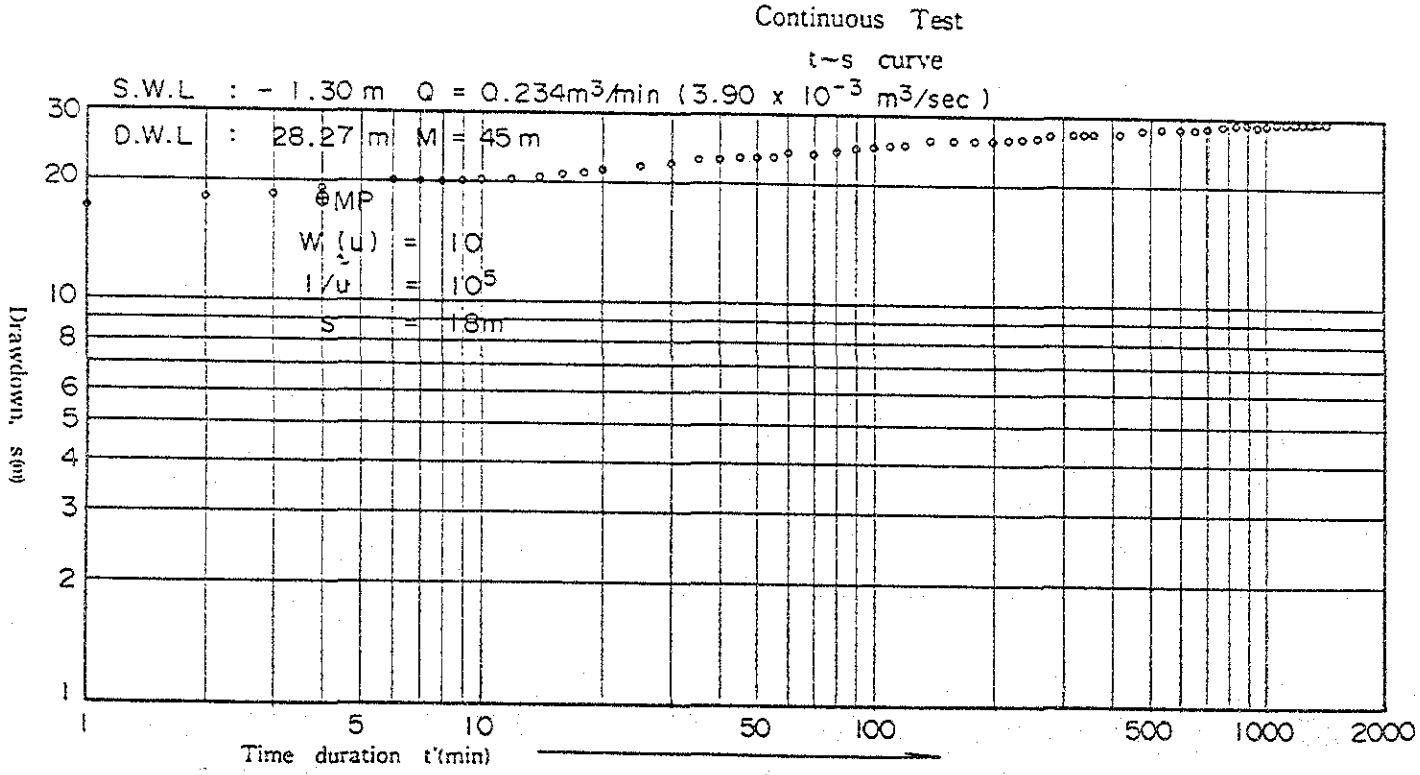
Fig. B.3.13 Continuous Test (Ow-1)

Water Level-Time Curve



22nd –23rd Dec.1988

Fig. B.3.14 Aquifer Test (Cotinuous Test)(OW-1)



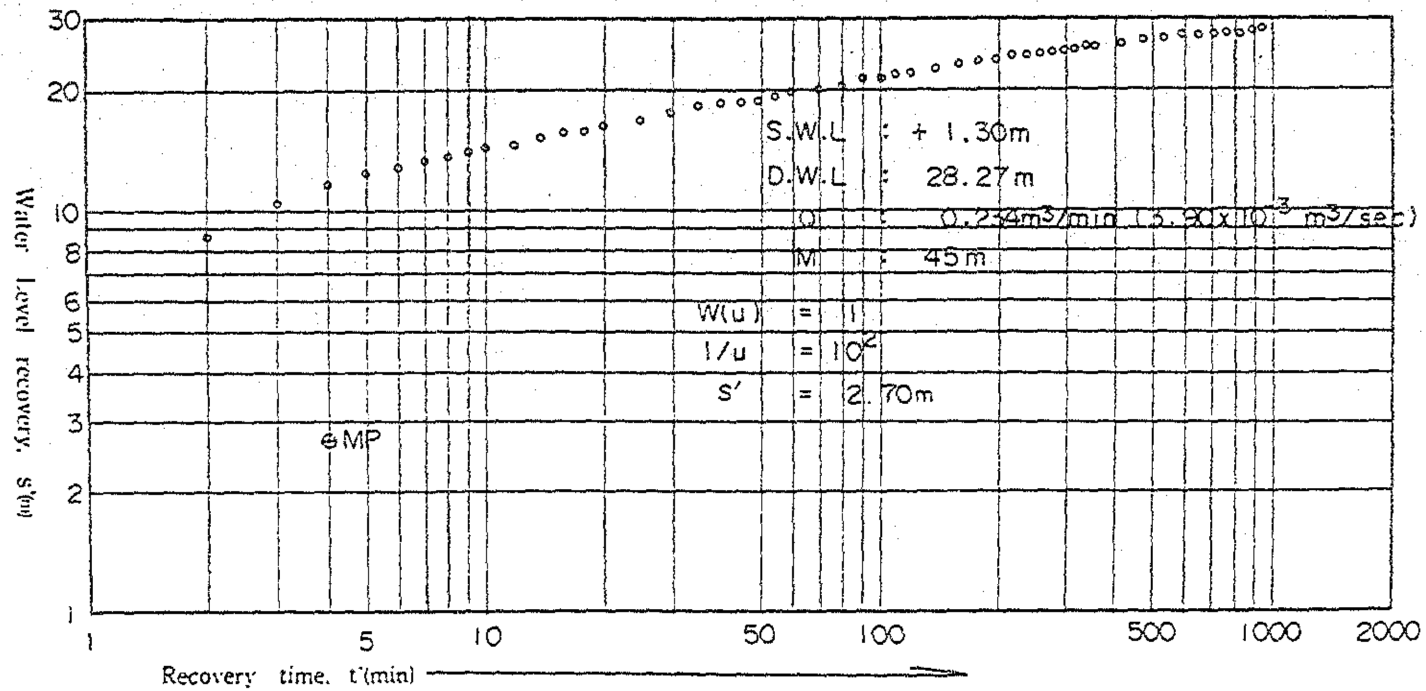
$$T = \frac{0.0796\,Q}{S} W(u) = \frac{0.796 \times 3.90 \times 10^{-3}}{18} \times 10 = 1.72 \times 10^{-4}\ m^2/sec$$

$$k = \frac{T}{M} = \frac{1.72 \times 10^{-4}}{45} = 3.83 \times 10^{-6}\ m/sec = 3.82 \times 10^{-4}\ cm/sec$$

22nd～23rd Dec.1988

Fig. B.3.15 Aquifer Test (Recovery Test)(OW-1)

Recovery Test t'～s' Curve



$$T = \frac{0.0796Q}{S'} W(u) = \frac{0.0796 \times 3.90 \times 10^{-3}}{2.70} \times 1 = 1.15 \times 10^{-4}\ m^2/sec$$

$$k = \frac{T}{M} = \frac{1.15 \times 10^{-4}}{45} = 2.56 \times 10^{-6}\ m/sec = 2.56 \times 10^{-4}\ cm/sec$$

Fig. B.3.16 Location Map (TW-1)

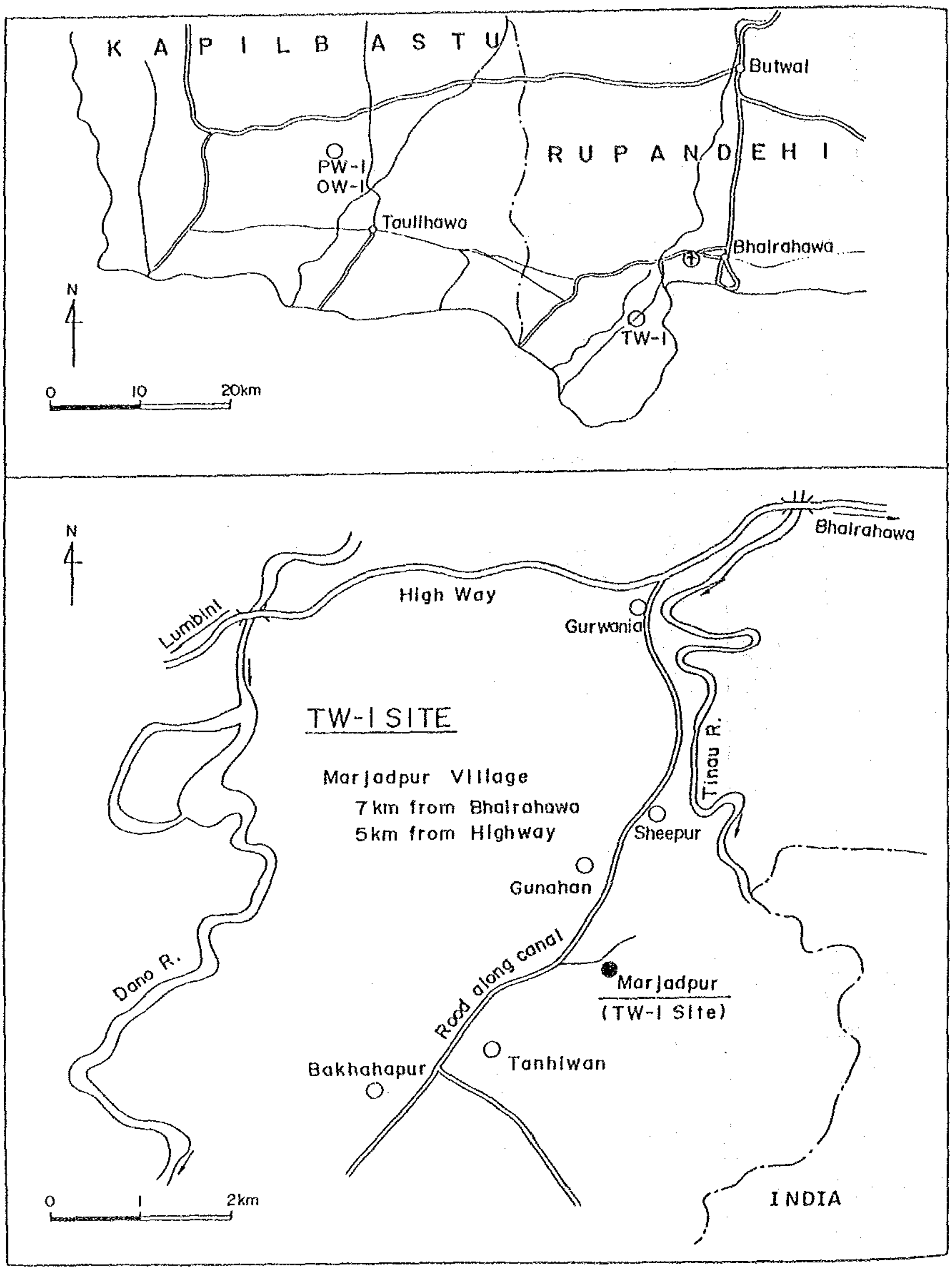


Fig. B.3.17 Well Log (TW-1)

PROJECT NAME THE INTEGRATED RURAL DEVELOPMENT PROJECT IN THE LUMBINI ZONE		WELL NO TW-1
AREA AND LOCATION		
ELEVATION m	LATITUDE	LONGITUDE
TOTAL DEPTH G.L-200.0 m	DRILLING RIG TOM-70 ROTARY TYPE	
DRILLING STARTED 12 JANUARY 1989	DRILLED BY A.B. SHRESTHA	
WELL COMPLETED 7 FEBRUARY 1989	LOGGED BY R. GAUTAM	

STATIC WATER LEVEL	G.L+7.75 m	WATER TEMPERATURE	26.2 ℃
DYNAMIC WATER LEVEL	G.L-2.00 m	CONDUCTIVITY	0.5 mU/cm
PUMPING RATE	461.4 l/min (664 m³/d)	pH	7.1
SPECIFIC CAPACITY	68.1 m³/d/m	TOTAL HARDNESS	255

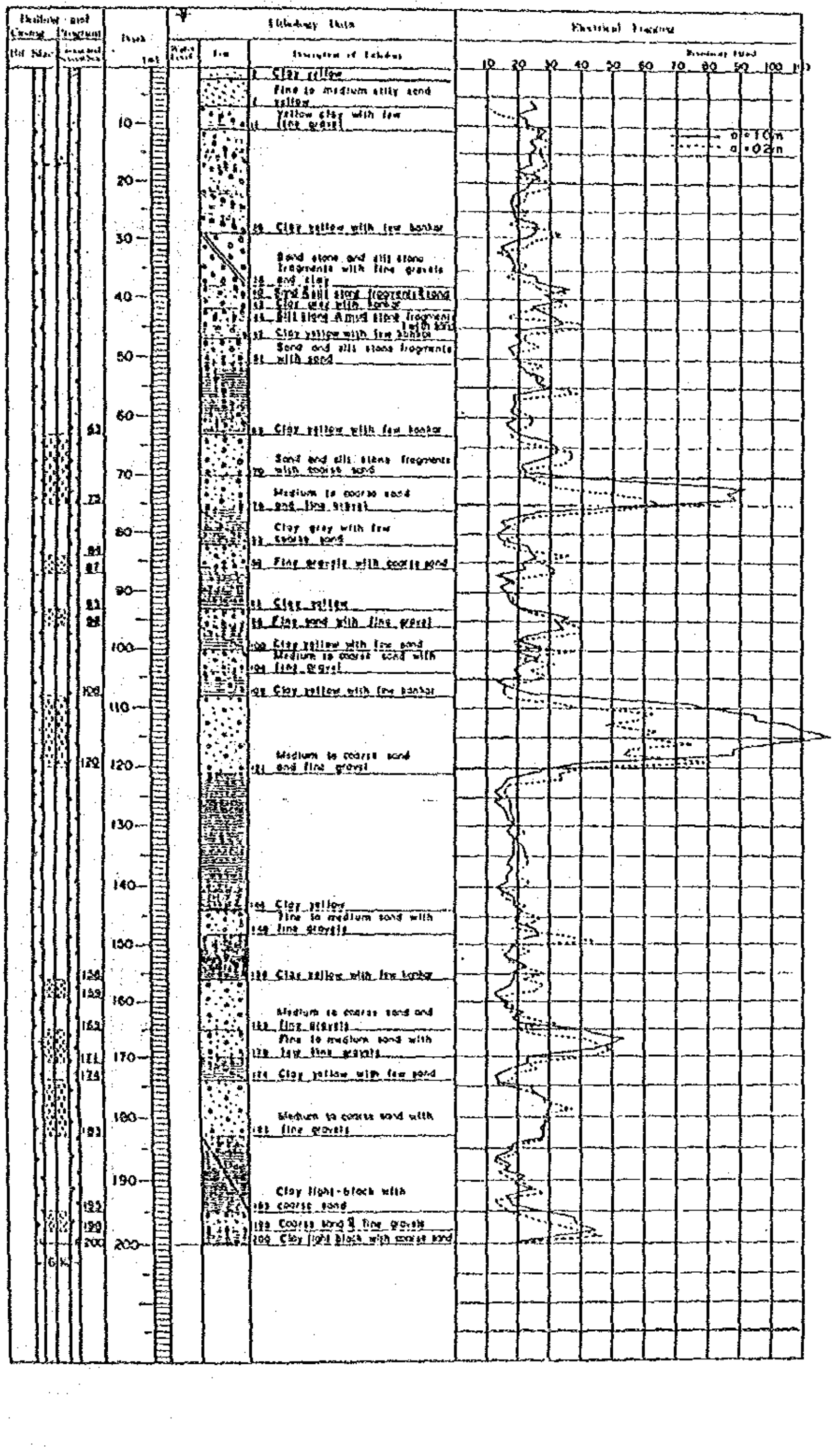
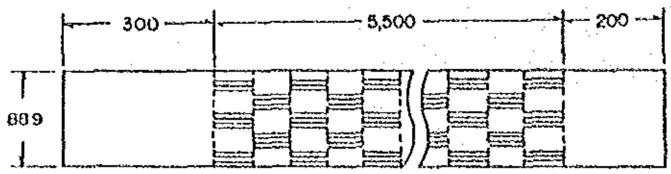
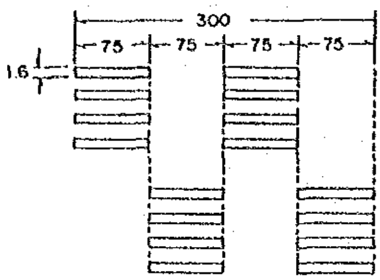


Fig. B.3.18 Opening Ratio of Slotted Screen Pipe and Chemical Components (TW-1)

3" SLOTTED SCREEN PIPE

UNIT : mm





No. OF SLOT PER ROUND = 84 No.

SURFACE AREA $A = \pi DL = 3.14 \times 88.9 \times 300 = 83,743\,mm^2$

OPENING AREA $A' = 1.6 \times 75 \times 84 = 10,080\,mm^2$

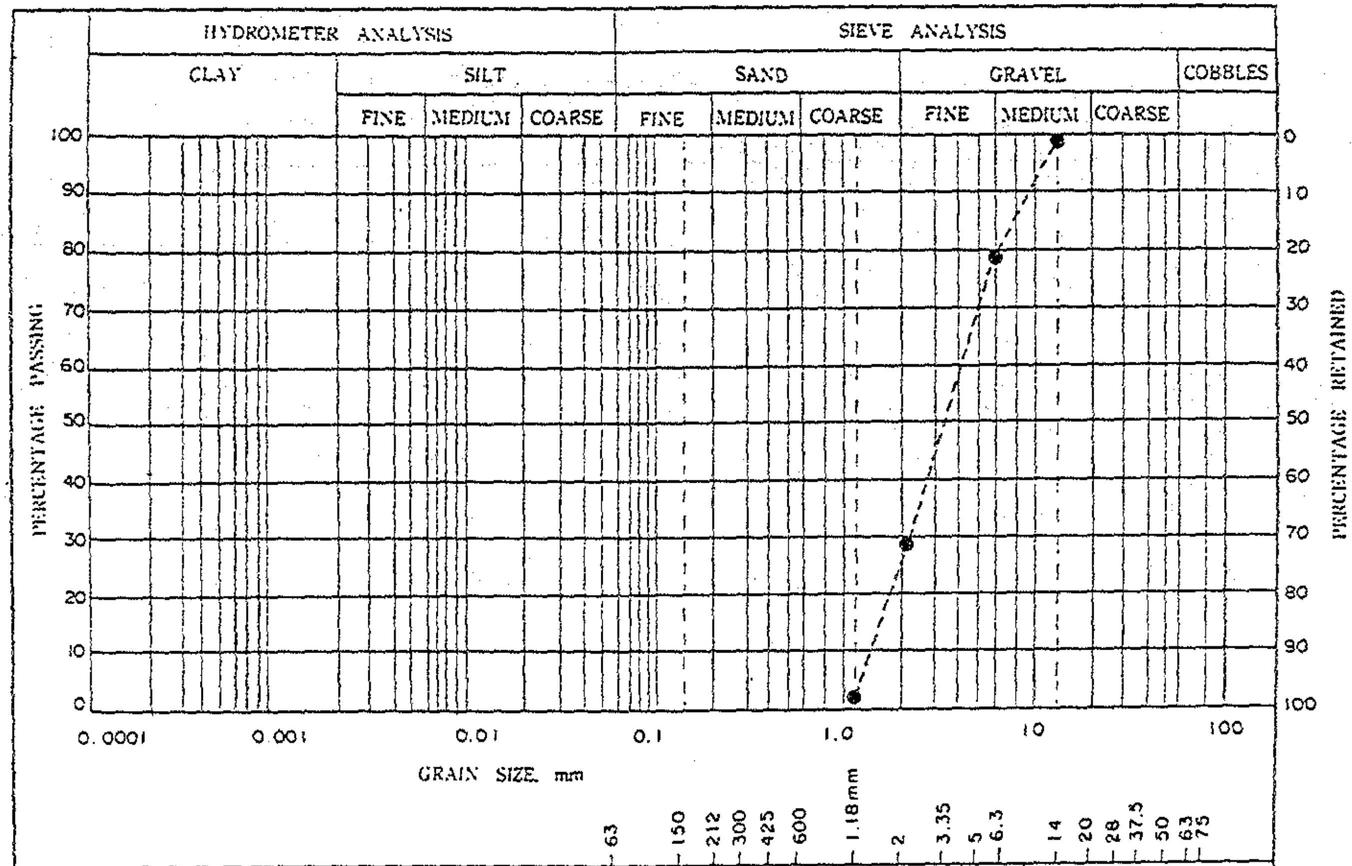
OPENING RATIO $A'/A \times 100\% = \underline{12.0\%}$

CHEMICAL COMPONENTS

Temperature	°C	15.0 (26.2)	Ca	mg/ℓ	49.82
pH		7.1 (7.1)	Mg		31.71
Electrical Conductivity	ms/cm	- (0.5)	Fe		0.415
Total Solids	mg/ℓ	29.0	Mn		0.005
Total Alkalinity		288.4	SiO_2		10
Total Hardness		255.0	Cl		7.68
Ammonia Total		0.32	SO_4		—

( ) measured in the field

Fig. B.3.19 Gradation Curve for Gravel Pack Materials (TW-1)



SYMBOL	BORE HOLE	DEPTH m.	DESCRIPTION OF SOILS	d_{60}	d_{10}	u	REMARKS
			Medium to fine gravel	4.0	1.5	2.7	

4th-5th Feb.1989

Fig. B.3.20 Continuous Test (TW-1)

Water Level-Time Curve

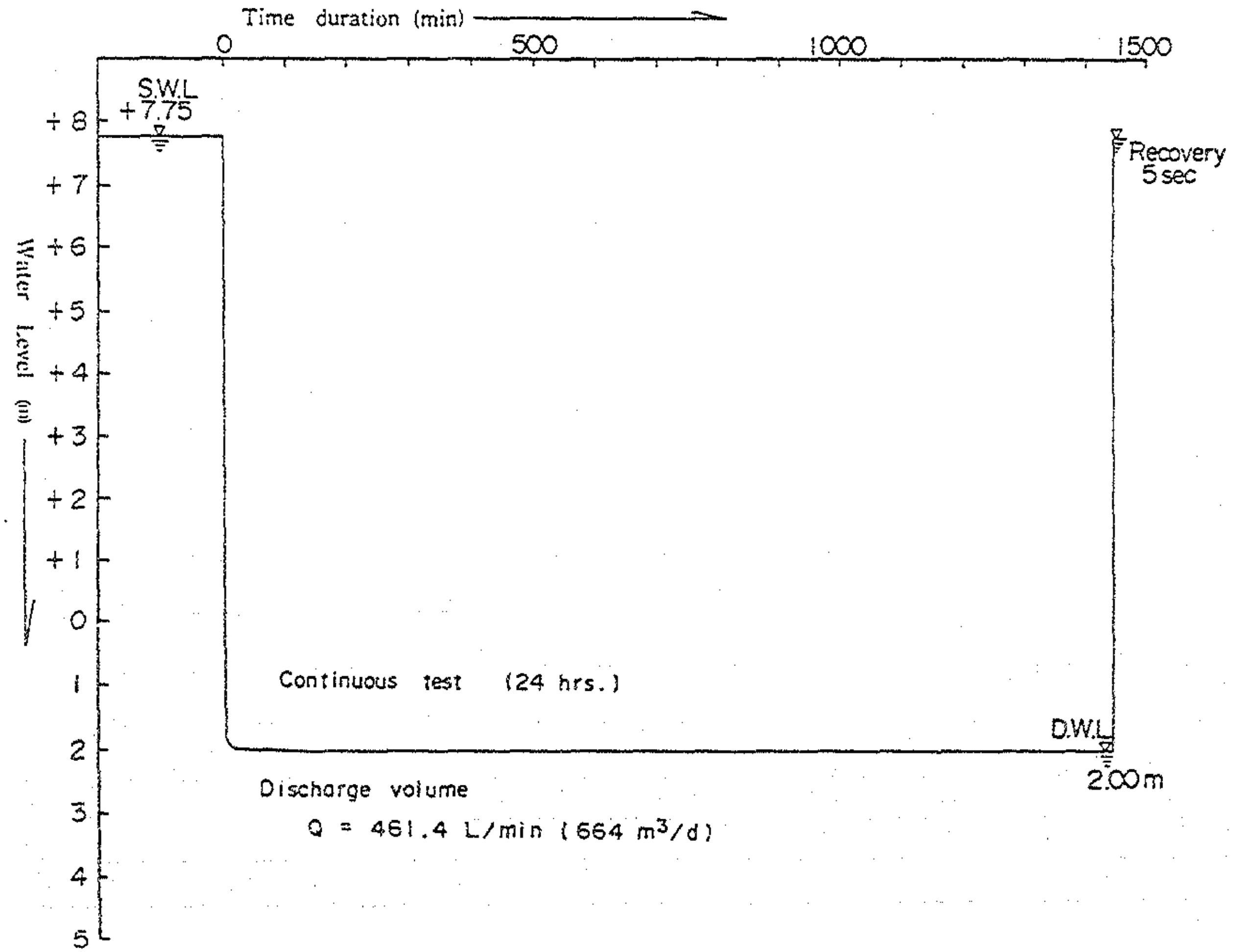
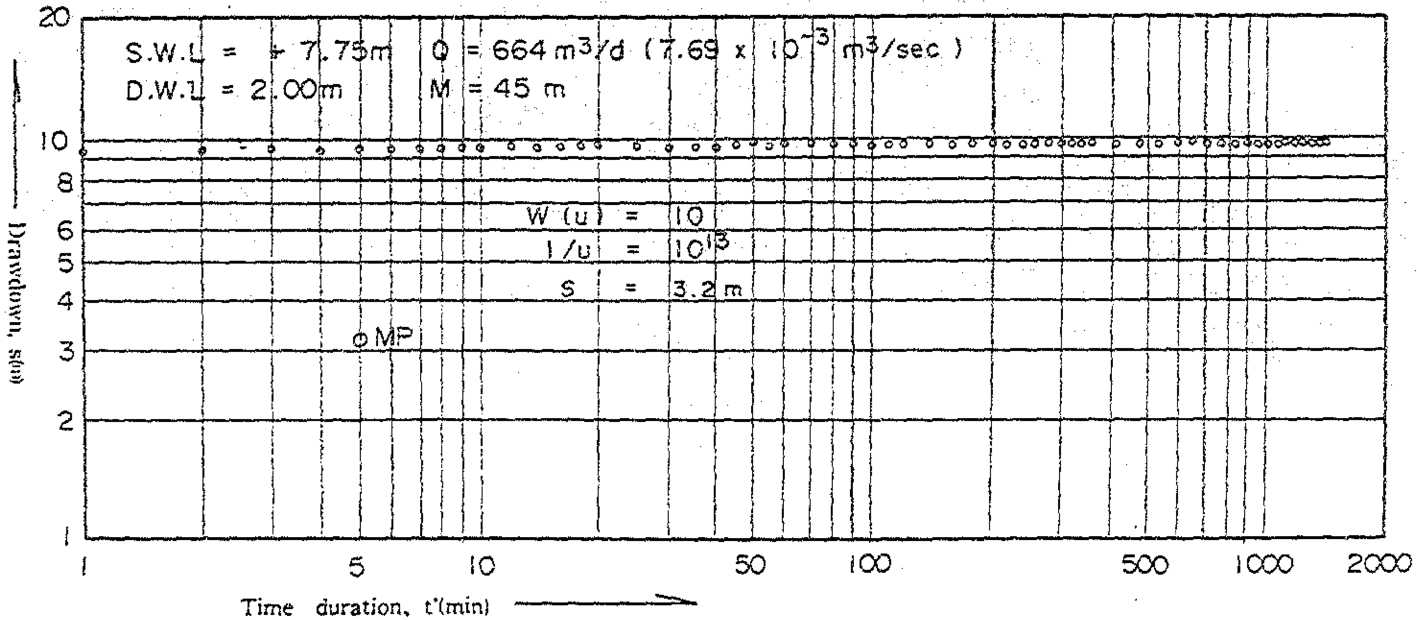


Fig. B.3.21 Aquifer Test (Continuous Test)(TW-1)

Continuous Test
t~s curve



$$T = \frac{0.0796\ Q}{s} W(u) = \frac{0.0796 \times 7.69 \times 10^{-3}}{3.2} \times 10 = 1.92 \times 10^{-3}\ m^2/sec$$

$$k = \frac{T}{M} = \frac{1.92 \times 10^{-3}}{45} = 4.27 \times 10^{-5}\ m/sec = 4.27 \times 10^{-3}\ cm/sec$$

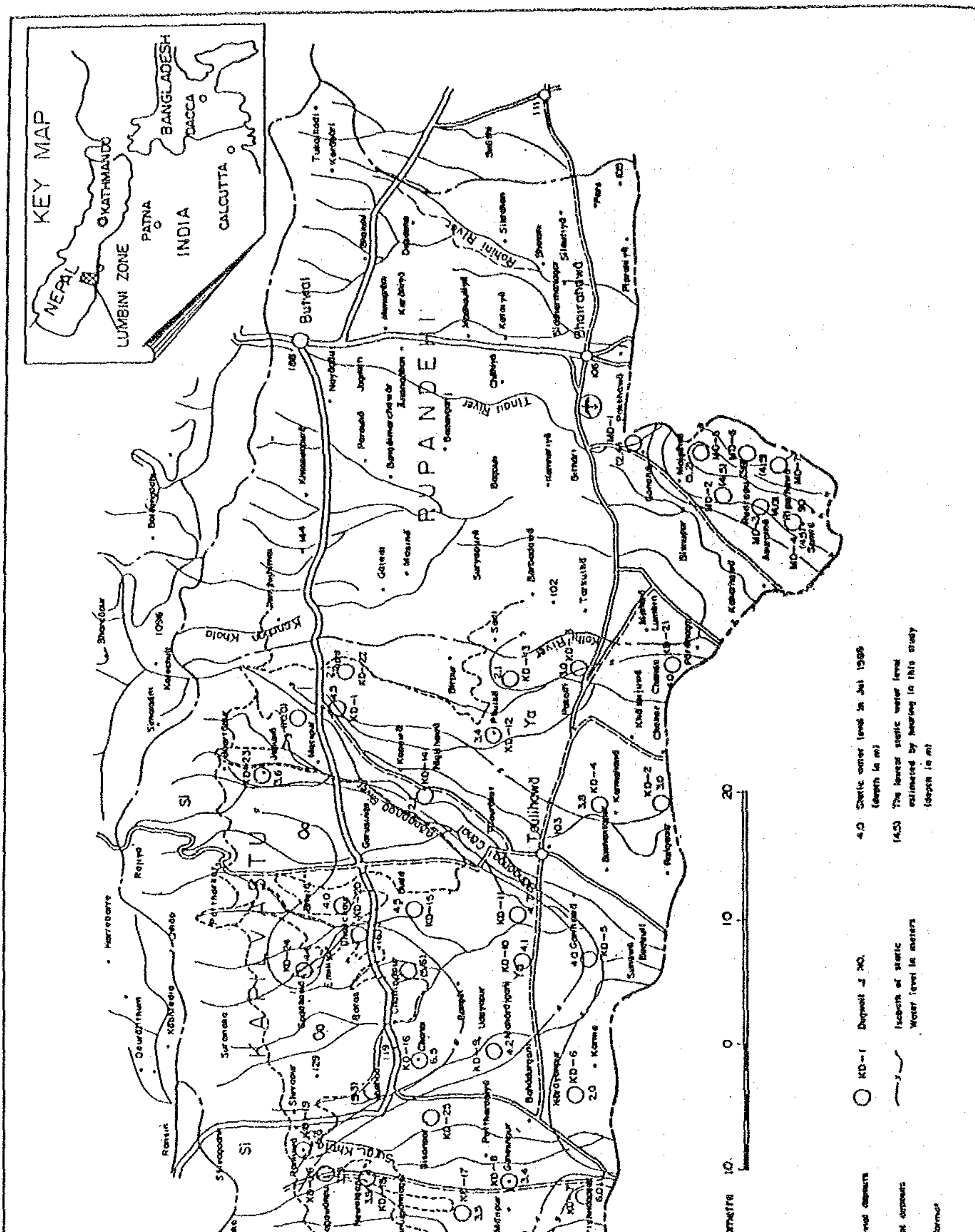


Fig. B.4 Location Map and Static Water Level (Dugwell)

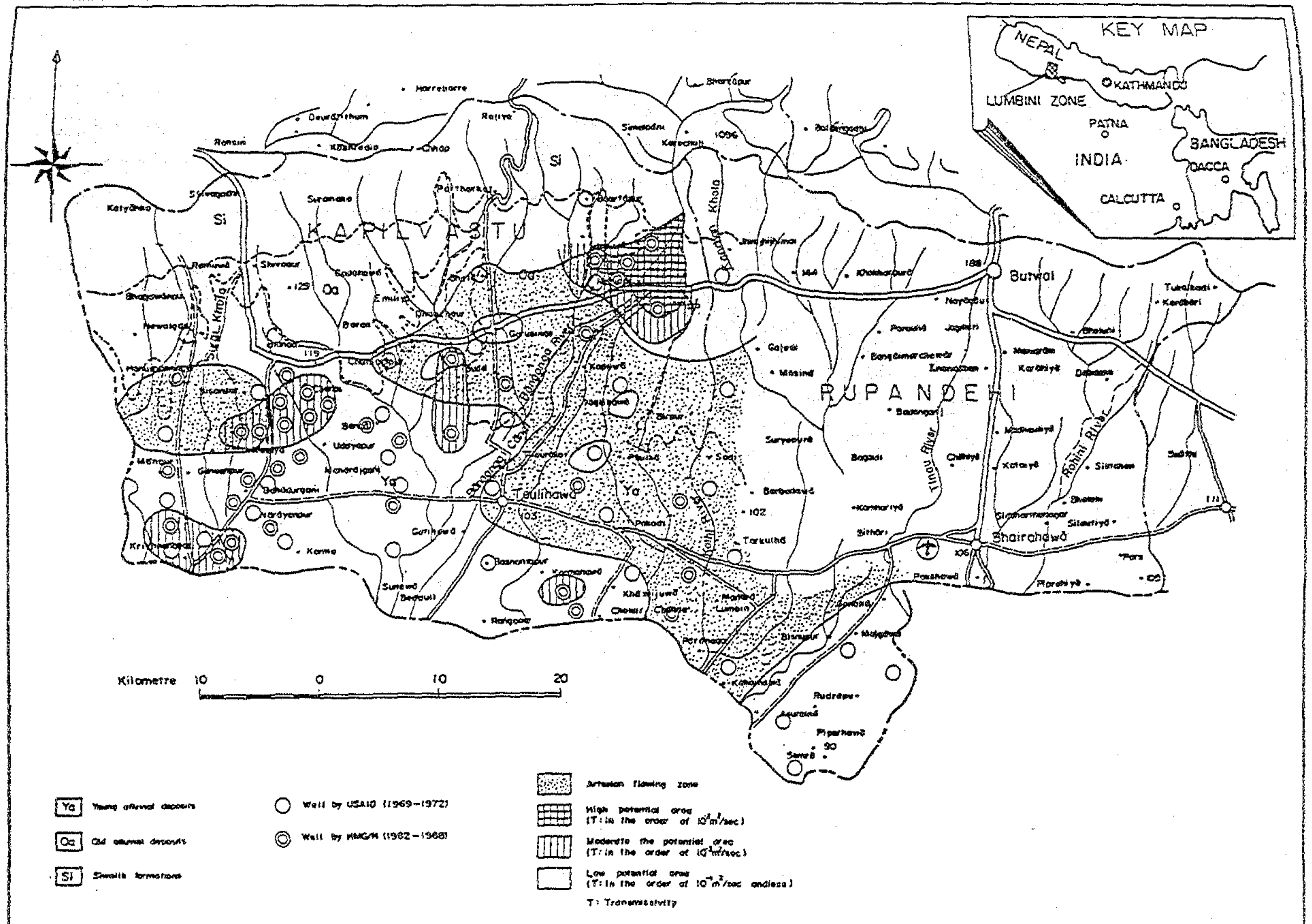


Fig. B.5 Groundwater Potential Map of Existing Deep Tubewell

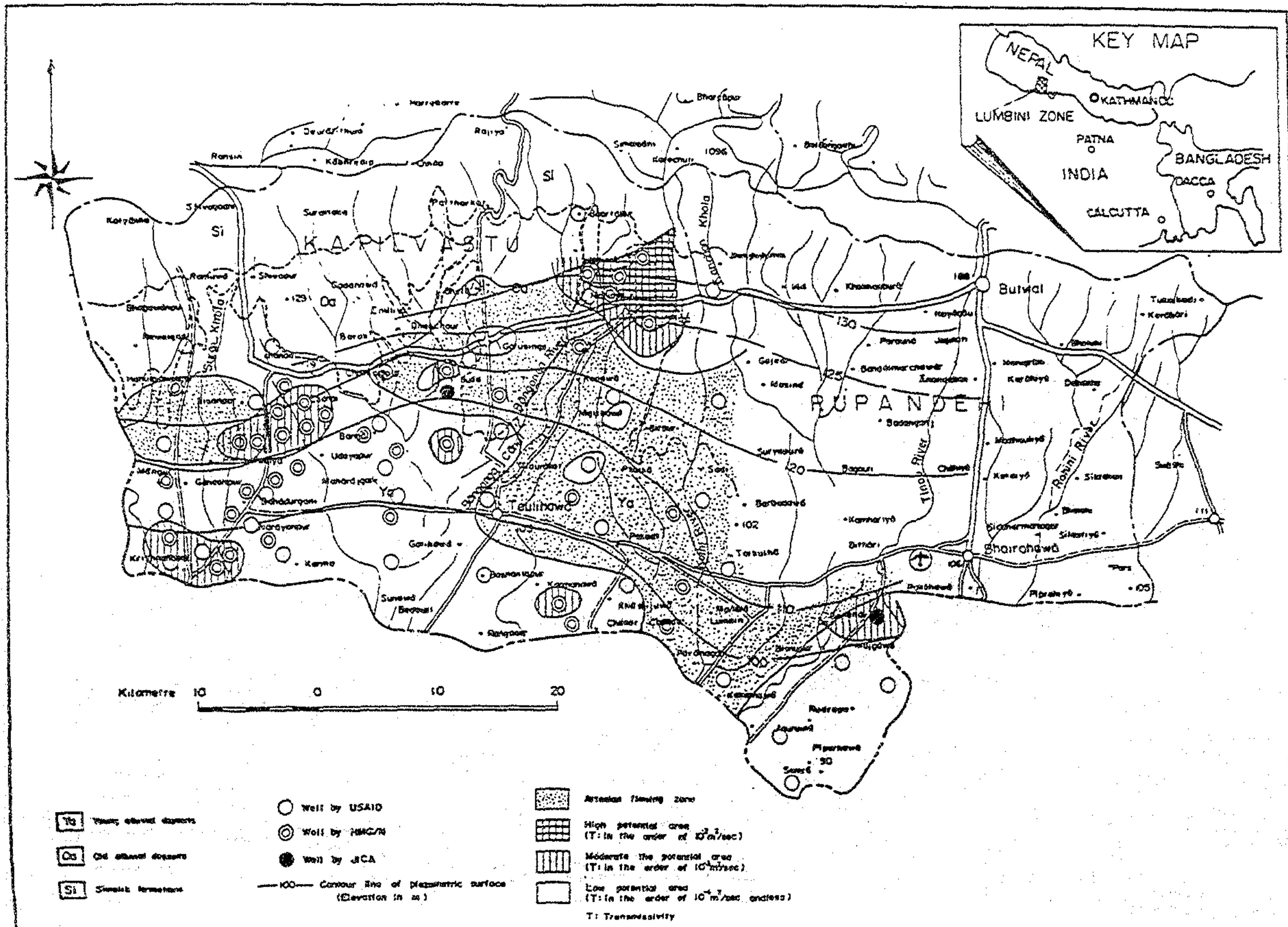
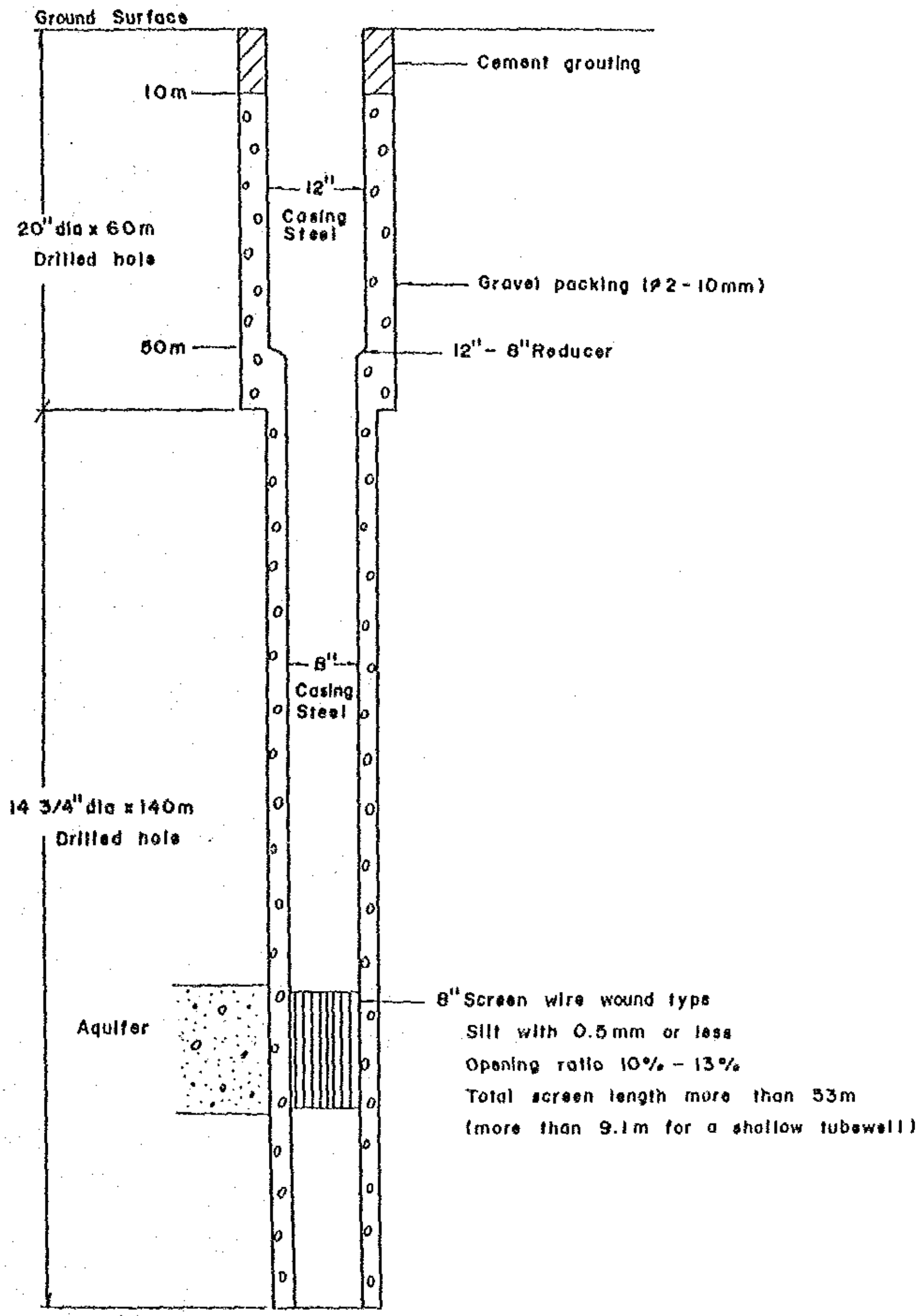


Fig. B.6 Groundwater Potential Map and Contour Map of Piezometric Surface

Fig. B.7 Standard Well Design (Deep Tubewell)



ANNEX C

IRRIGATION

THE MASTER PLAN STUDY
ON
THE INTEGRATED RURAL DEVELOPMENT PROJECT
IN
THE LUMBINI ZONE

ANNEX C IRRIGATION

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1. METEOROLOGY AND HYDROLOGY

1.1 Meteorology

1.1.1 Meteorological Stations

According to the "Climatological Records of Nepal", there are 11 major meteorological stations in the project area. Out of them temperature, relative humidity, rainfall, etc. are observed the following six stations:

Table C.1 List of Meteorological Stations

Name of station	District	Period of available data
703 Butwal	Rupandehi	1976,1982-1986
705 Bhairahawa Airport	Rupandehi	1976-1986
707 Bhairahawa (Agri)	Rupandehi	1976-1986
715 Khanchikot	Arghakhanchi	1977-1986
716 Taulihawa	Kapilvastu	1979-1986
725 Tamghas	Gulmi	1981-1986

At the remained four stations, only rainfall is observed

Table C.2 List of Rain Gauges

Name of station	District	Period of available data
701 Ridi Bazar	Gulmi	1976-1986
721 Patharkot West	Kapilvastu	1976-1986
722 Musikot	Gulmi	1976-1986
723 Bhagwanpur	Kapilvastu	1976-1986
727 Lumbini	Rupandehi	1981-1986

The location of the above stations are shown in Fig. C.1.

1.1.2 Meteorological Data

(1) Kapilvastu District

The meteorological data observed at Taulihawa, Bhagwanpur and Patharkot West located in Kapilvastu district are summarized in Table C.3 and Table C.9.

(2) Rupandehi District

The meteorological data observed at Bhairahawa(Agri) and Lumbini located in Rupandehi district are summarized in Table C.4 and Table C.9. Since wind velocity and sunshine hours are not available at Bhairahawa Airport (Table C.5) nor Butwal (Table C.6), the data of these two stations are used only for reference checks on the Bhairahawa (Agri) data.

(3) Gulmi District

The meteorological data observed at Tamgas, Ridi Bazar and Musikot located in Gulmi district are summarized in Table C.7 and Table C.9.

(4) Arghakhanchi

The meteorological data observed at Khanchikot located in Arghakhanchi district is summarized in Table C.8.

1.1.3 Climate

The project area of the Lumbini Integrated Rural Development Project (IRDP) is comprised of four administrative districts i.e. Gulmi, Arghakhanchi, Kapilvastu and Marchawar area in Rupandehi district. The area lies between 27°20' to 27°55' north latitude and 82°42' to 83°25' east latitude. The climate of the project area as well as Nepal is strongly affected by the southeast monsoon during the rainy season and the northwest monsoon during the dry season. These monsoons distinctly divide the climate into two said seasons. The rainy season generally lasts from June to September, while the dry season is from November to April. May and October are transition period of these seasons. In general, it is humid and hot in the rainy season or summer, while it is dry and cool in the dry season or winter. Annual rainfall varies from 1,600 mm to 2,000 mm from place to place. More than 90% of annual rainfall occurs in the rainy season. This is due to the influence of the said southeast monsoon.

In terms of altitude, climate in Nepal is generally divided into five climatic zones, i.e. Arctic, Alpine, Cool Temperature, Warm Temperature and Sub-tropical. Altitude in Gulmi and Arghakhanchi districts, so called hill area, varies from about 600 m to more than 2,000 m. The climate in the two districts is classified into Warm Temperature and Cool Temperature. Those in Kapilvastu and Rupandehi districts, so called Terai plain, is from 90 m to 150 m. Climate in these districts is classified into Sub-tropical. The mean annual temperature is about 24.5°C at Bhairahawa. From November to February the weather is cool with a mean temperature about 18.0°C; March to October is the warm or hot season, having a mean temperature of 28.0°C.

1.2 Hydrology

1.2.1 General

Nepal is a landlocked country. Rivers generally originate in and around the hill ranges and flow out India through Terai Plain. Rivers generally flow in north - south direction in the Terai plain.

The numbers of rivers and streams were identified in the water use inventory study of Gulmi, Arghakhanchi, Kapilvastu and Rupandehi districts conducted by the Water and Energy Commission in 1987/88, 1988/89, 1986/87 and 1984/85 respectively. In the same study, mean monthly flows of major rivers and streams were analyzed in the form of predicted hydrograph.

1.2.2 Hydrology

(1) Gulmi District

1) Rivers

This district is located the most north in the project area and is topographically classified into hill area. 69 rivers and streams which flow through or originate in the district were identified in the said study. Of them 64 rivers are tributaries of Kali Gandaki river which runs eastern boundary of the Gulmi District. Total catchment of those 64 rivers shares more than 95% (1,025 km^2) of the total area of Gulmi district. After joining with these tributaries, the Kali Gandaki flows out from the district to eastern and never flow into the project area again. The remained 5 rivers having 54 km^2 of catchment area are tributaries of the Jhimruk river which flows southerly with western boundary of the Gulmi and Arghakhanchi districts. The Jhimruk river is a tributary of the Rapti river which does not flow into the project area as the Kali Gandaki does not.

The name and location of the major rivers are shown in Fig.C.2.

2) Hydrological Observations

There is a hydrological station at Set Beni in the Kali Gandaki. Mean monthly discharge at this station is available for three years. Besides discharge measurement were made irregularly at some stations. Measured data are, however, very insufficient to directly estimate water resources of the rivers in the district, though the water use inventory study made additional discharge measurements at 19 rivers in 1988.

3) Mean Monthly Flow

In the water use inventory study the mean monthly flow of the major rivers and streams are predicted by applying typical monthly hydrograph established for every hydrological region in Nepal. The results are summarized in Table C.10.

(2) Arghakhanchi District

1) Rivers

This district is located the south of Gulmi district and is topographically classified into hill area as Gulmi district is. 65 rivers and streams which flow through or originate in the district were identified in the said study. Of them 34 rivers are tributaries of Ridi Khola which runs eastern boundary of the Arghakhanchi district. Total catchment of those rivers shares about 35% (432 km^2) of the total area of Arghakhanchi district. After joining with these tributaries, the Ridi Khola flows easterly and joins with the Kali Gandaki. 12 rivers are tributaries of the Jhimruk river which flows the western boundary of the Gulmi and Arghakhanchi districts. The Jhimruk river is a tributary of the Rapti river which does not flow into the project area as the Kali Gandaki does not. 6 rivers directly flow into the Rapti river. Total catchment area of all tributaries of the Rapti river shares about 50% (616 km^2) of the district. The remained 13 rivers sharing 15% (185 km^2) are tributaries of the Banganga river. The Banganga river flows southerly and flows into Kapilvastu district.

The name and location of the major rivers are shown in Fig.C.3.

2) Hydrological Observations

There are hydrological stations at Bagasoti Gaon in the Rapti river and at Tigra village in the Jhimruk river. Mean monthly discharge at these stations are available for 10 years and 18 years respectively. Besides discharge measurement were made irregularly at some stations. Measured data are, however, very insufficient to directly estimate water resources of the rivers in the district, though the water use inventory study made additional discharge measurements at 43 rivers in 1988.

3) Mean Monthly Flow

In the water use inventory study the mean monthly flow of the major rivers and streams are predicted by applying typical monthly hydrograph established for every hydrological region in Nepal. The results are summarized in Table C.11.

(3) Kapilvastu District

1) Rivers

This district occupies southwestern part of the project area and is located south of Arghakhanchi district. The Chullia hills runs from east to west is a boundary between Kapilvastu and Arghakhanchi districts. From the foot of the Chullia hills the district has a gentle slope from north to south and is classified into Terai plain. 55 rivers and streams which flow through or originate in the district were identified in the water use inventory study. Only the Banganga is the river flows into from the Arghakhanchi district; all other rivers originate southern slope of the Chullia hills or Terai plain.

The name and location of the major rivers are shown in Fig.C.4.

2) Hydrological Observations

There is one hydrological station on the Banganga river at Bagaicha near Taulihawa, but up-to-date data could not be available. Although the water use inventory study made discharge measurements at 12 rivers in 1987, measured data are very insufficient to directly analyze water resources of the rivers and streams in the district.

3) Mean Monthly Flow

In the water use inventory study the mean monthly flow of the major rivers and streams are predicted by applying typical monthly hydrograph established for every hydrological region in Nepal. The results are summarized in Table C.12.

(4) Rupandehi District

1) Rivers

This district occupies southeastern part of the project area and is located south of Arghakhanchi district and Palpa district outside of the project area. The Chullia hills runs from east to west is a boundary between Rupandehi and those two districts. From the foot of the Chullia hills the district has a gentle slope from north to south and is classified into Terai plain.

24 rivers and streams which flow through or originate in the district were identified in the water use inventory study. Only the Tinau is the river flows into from northern outside; all other rivers originate southern slope of the Chullia hills or Terai plain.

The name and location of the major rivers are shown in Fig.C.5.

2) Hydrological Observations

There is one hydrological station on the Tinau river. The station is located near suspension bridge about 4 km downstream from Dhobhan Khola at Butwal. Mean monthly discharge at this station are available from 1964 to 1969. Measured data are very insufficient to directly estimate water resources of the rivers, though the water use inventory study made discharge measurements in more than 20 rivers in 1985.

3) Mean Monthly Flow

Mean monthly flow on the Tinau river from 1964 to 1969 is shown in Table C.13. The observed data by the water use inventory study for some rivers are also shown in the Table C.13.

1.2.3 Surface Water Resources

Conceivable water resources in the hill area i.e. Gulmi and Arghakhanchi districts are: (a) river and stream flow particularly in the rainy season; and b) springs most of which are perennial but have small flow, and those in the plain of Terai plain i.e. Kapilvastu and Rupandehi districts are: c) river and stream flow particularly in the rainy season; d) groundwater to be tapped from dug wells and tubewells; and e) water in the reservoirs and ponds to be filled with in the rainy season.

Most of the rivers in the project area has small catchment and very small flow even in the rainy season and nearly dry up in the dry season. The numbers of the rivers which have comparatively large flow are limited as follows:

Gulmi district	;	Kali Gandaki, Badi Gad, Chaldi Khola, Ridi Khola
Arghakhanchi district	;	Rapti, Jhimruk, Sisne
Kapilvastu district	;	Banganga, Murthi, Kothi, Arra Nala
Rupandehi district	;	Tinau, Dano

The above rivers and other major rivers have been already utilized for water sources for irrigation particularly in the rainy season, except the Kali Gandaki, the Ridi Khola, and the Rapti rivers. Because these three rivers are very large and form deep gorges in the project area, several comprehensive water resources development plans must be studied in the first place and considerably large amount of investment will be required for its implementation.

As mentioned in the following sections, in general, water utilization is not yet systematically organized in the project area in spite of limited resources. In this project, development of surface water resources is to be mainly in re-development of existing water resources rather than new water resources development in the Terai plain and utilization of rivulets and springs in the hill area.

2. PRESENT CONDITION

2.1 Irrigation Area

The present area of cultivated lands under irrigation in the four objective districts is as follows:

Table C.14 Present Irrigation Area

District	(1) Cultivated Land (ha)/1	(2) Land under Irrigation (ha)/2	(2)/(1) Irrigation Percentage (%)
Kapilvastu	84,730	25,320	29.9
Rupandehi	87,210	31,540	36.2
Gulmi	25,600	1,840	7.2
Arghakhanchi	19,960	2,260	11.3

/1 : The Land Resources Mapping Project (LRMP) in 1986.

/2 : The figures are estimates of irrigation-command areas where supplemental water is provided for at least the rainy season paddy. Area where year-round irrigation is practiced is smaller than the figures.

As shown in the above table, there is a great difference in the irrigated area between the first two districts in the Hill and the other two districts in the Terai, with far larger area under irrigation in the Terai.

The national averages for the cultivated area with irrigation facilities as percentage are: 21% for the Terai and 11% for the Hill. Comparing the figure of the four districts with the national averages, the irrigated lands in the two districts in the Hill are less than or equal to the national average, but on the contrary, those in the two districts in the Terai are higher than the national average.

The higher irrigation percentage in the Rupandehi is contributed by both three national irrigation projects comprising Bhairahawa-Lumbini Groundwater Project, Siyari Irrigation Project and Tubewell Water Use and Distribution Project and 10 nos. of farmers' irrigation schemes, including Sorah - Chatti's Mahja Kulo Scheme, Panch Majha - Aath Majha Kulo Scheme, Mahau Irrigation Scheme, etc. Likewise, the high percentage in the Kapilvastu is the result from both three national projects consisting of Banganga Irrigation

Project, Surai Irrigation Project and Jamai Irrigation Project and 132 nos. of farmers' irrigation schemes such as Bhutaha Bandh Scheme, Murthi Nala Scheme, Pattharkot Bandh Scheme, etc.

On the other hand, the low irrigation percentages in Gulmi and Arghakhanchi districts are attributed to both limited water resources and complicated topography in the hill areas, though 121 nos. and 179 nos. of farmers' irrigation scheme exist respectively.

In general, irrigation in the farmers' schemes is confined only to paddy cultivation only in the rainy season.

2.2 Existing Irrigation Projects and Schemes

2.2.1 Existing Projects

There are a great number of existing irrigation projects and schemes constructed by HMG/N and the farmers' communities in the four objective districts in the Lumbini Zone. The numbers of such projects and schemes can be summarized as follows:

Table C.15 Numbers of Existing Project and Scheme

District	HMG/N's Project	Farmers' Scheme
Kapilvastu	3 (3)	132 (10)
Rupandehi	4 (4)	10 (4)
Gulmi	2 (2)/1	121 (1)/1
Arghakhanchi	0	179 (3)

Source : The Water Use or Resources Inventory Study of Gulmi, Arghakhanchi, Kapilvastu and Rupandehi Districts conducted by the Water and Energy Commission from 1984/85 to 1988/89.

/1 : The bracketed figures show the number of the projects and schemes which have permanent irrigation systems.

However most of the existing projects and schemes use irrigation for the rainy season paddy only since their water sources have sharply decreased or dried up in the dry season as described the following section.

The HMG/N's projects are generally comprised of diversion weir, intake, irrigation canals, etc. Diversion weir is generally of overflow weir type with under sluice equipped with gate. Intake structure are also equipped with gate. However, some of these gates do not function well due to deterioration. The irrigation canals are generally of earthen canal having trapezoidal section. In some projects, main canal losses the original flow capacity due to sedimentation and weed. Water measuring devices are not installed in almost all the projects.

In the farmer's scheme, diversion structure is generally run-of-river type and made of earth, stones and woods. No gate is equipped. Irrigation canals are generally of earthen trapezoidal type.

The name of major projects and schemes are listed in Table C.16. Location of those are shown in Fig. C.6. Present condition of those are described in Appendix C-1 in this report and summarized in the following section 2.2.3.

2.2.2 Under Construction Projects

Apart from the existing irrigation projects, several irrigation projects and scheme are being constructed by the Department of Irrigation (DOI) and District Panchayats (DPs). Those are also listed in the Table C.16.

Among the above-mentioned projects in the four Districts, location of DOI projects are shown in Fig. C.6.

2.2.3 Current Situation and Problems

More than 90% of the rainfall occurs in the rainy season from June to September. In the dry season, irrigation is indispensable for intensive agriculture particularly from March to May. In the rainy season, drought days often continue in more than one week so supplemental irrigation is required.

Most of the existing projects depend on the irrigation water resources of the rivers. Those rivers generally has very small catchment area so its flow is small and unstable even in the rainy season. In the dry season, most of the rivers are dry up. Irrigation is quite limited or unable in the dry season. Rivers also carry so much sediment in the rainy season. The sediment directly flow into the intake and canals and accumulate resulting in decreasing their original function.

Several projects does not necessarily function well due to damage, breakage, sediment, erosion and scouring of weirs, intakes, canals and the related structures mainly by flood and embankment sliding. Those are Surai and Jamai in Kapilvastu, and Siyari, Sorah - Chattis Mahia Kulo and Panch Majiha - Aath Majha Kulo projects in Rupandehi. In Banganga Project in Kapilvastu, weed grows very thick in the canals due to the slow velocity of water. Weeding work is done by the villagers participation but such work is a heavy burden for villagers. Because few water control facilities such as gates and measuring devices are constructed in the canals, effective use and even distribution of water is hardly done in the many projects.

So many temporary diversion structures are constructed by village Panchayats in the rivers. Although the river water is very limited, villagers usually take water at their convenience so that water is not available at the intake located downstream even though during the rainy season. Several villages frequently dispute each other. In order to solve such dispute and realize the effective use and even distribution of water, adjustment and integration of the existing water right has to be made; however, it may take an extremely long period of time.

Several barrages or diversion works on the rivers are constructed in India near the border. The back water of these barrages frequently cause inundation in the rainy season. Some flood protection works such as construction of dikes and short cut of river channel is indispensable to protect farm lands from the inundation.

3. IRRIGATION DEVELOPMENT PLAN

3.1 Government's Policy for Irrigation Development

3.1.1 Target and Achievement of Development Works

The Government of Nepal has formulated a programme for agricultural development in which grain production of the country is planned to increase. Irrigation is considered to be the prime contributing factor in achieving the production increase. The Seventh Five Year Plan aims to:

(a) expand community owned and operated small scale irrigation schemes in the Hill areas using local skills and improved technologies, and

(b) develop medium and large scale irrigation projects in the Terai plain by improving water distribution systems, water management, and maintenance of irrigation facilities, by taking into account the geophysical and hydrological conditions in the Terai Plain.

The target of the Seventh Five Year Plan and achievement by the previous activities of irrigation development announced by the Government are summarized as follows:

Table C.17 Achievement and Target of Irrigation Development Works

Year	Target (ha, accumulated)	Achievement (ha)
1984/85 (end of Sixth Five Year Plan)	-	371,000
1986/87	-	434,000 (accumulated) incl. 357,300 by Gov. and 76,700 under ADB/N
1989/90 (end of Seventh Five Year Plan)	606,000	-
2000	1,250,000	Increment of 816,000 from 434,000 in 1986/87 consist of: 589,000 by DOI including, - 244,000 by small scale project, - 260,000 by medium & large scale, - 85,000 by groundwater, and 227,000 under ADB/N

DOI : Department of Irrigation, Ministry of Water Resources
ADB/N : Agricultural Development Bank of Nepal
Source : Working Policy on Irrigation Development for Fulfillment of Basic Needs

3.1.2 New Working Policy

To reinforce and accelerate the irrigation development works, a new working policy has been recently considered based on the evaluation and reflection on the past works. This new working policy has been adopted to develop irrigation projects guided by the same policy for all government and semi-government agencies. The main principles of the policy are:

(a) Beneficiaries' participation and consent will be made from the project identification, selection, design, construction to operation and maintenance,

(b) Contribution or share of the government for each project is fixed whatever the executing agency.

Surface irrigation system are classified as small, medium and large on the basis of the size of the command area that the project serves.

Table C.18 Classification of Project Types

Type of Irrigation System	Command Area (ha)	
	Hill Area	Terai Plain
Small	Less than 50, District level	Less than 500, District level
Medium	50 - 500, Central level	500 - 5,000, Central level
Large	Greater than 500, Central level	Greater than 5,000, Central level

3.2 Potential and Constraints of Development

3.2.1 Development Potential

As mentioned in the previous sections, in the area of IRDP, (a) the development of new water resources is limited, (b) the existing irrigation systems and facilities have not functioned well due to the breakage and deterioration, (c) water utilization is not yet systematically organized due to lack of water control facilities. Therefore, potential for irrigation development in the IRDP exists in re-development of the major rivers, streams and rivulets, in rehabilitation and upgrading of the existing irrigation systems and facilities including protection works of floods and land sliding. Development of large rivers such as Kali Gandaki, the Ridi Khola and Rapti have to be assessed by further studies. There exists less potential of new development of groundwater for irrigation based on the results of field investigation and data collection mentioned in the Annex B Hydrogeology.

According to the investigation carried out so far, the existing paddy area and the farm land under irrigation in the four objective districts are as tabulated below:

Table C.19 Existing Paddy Field

	Paddy Area/1	Farm Land under Irrigation		Balance (Rainfed)	
	(ha)	(ha)	(%)	(ha)	(%)
Kapilvastu	74,890	25,320	34	49,570	66
Rupandehi	76,090	31,540	41	44,550	59
Gulmi	4,030	1,840	46	2,190	54
Arghakhanchi	4,090	2,260	55	1,830	45

/1: The Land Resources Mapping Project (LRMP) in 1986.

Based on the result of field survey, the above figures may be interpreted as follows:

1) Rainfed culture is prevailing in the existing paddy areas;

2) The existing paddy areas are developed on most of lowlands along the rivers and streams in the hill districts and occupy almost all of the farm lands in the Terai districts:

3) It is hardly possible to further extend paddy areas in both hill and Terai districts because;

a) the lowlands along the rivers and streams in the hill districts have already been developed to the maximum extent as paddy areas, and

b) almost all of lowlands in the Terai districts have been developed as paddy areas and there are no room for further expansion of the paddy areas.

However, it seems that there are considerable potential for expansion of irrigable land in the existing paddy areas in both hill and Terai districts. The potential will be able to be developed by the following possible ways:

(a) Construction of diversion weir to irrigate paddy areas in the plain districts;

(b) Construction of ponds to store rain and flood in the rainy season;

(c) Rehabilitation of existing irrigation systems and facilities together with construction of flood protection dikes and river training, for mitigating flood damage to and enlarging the paddy areas;

(d) Effective and rational use of existing irrigation systems and facilities by saving water losses, constructing protection works and introducing improved water management and operation and maintenance techniques;

(e) Further development of surface water resources particularly in the hill districts by constructing intakes in the mountain stream and introducing sprinkler irrigation; and

(f) Use of handy type centrifugal pumps equipped with diesel engine, to pump up water from rivers and streams particularly in the dry season;

The tentative potential of irrigation development in the existing paddy area is assessed as follows. The estimation is based on the existing project list obtained through DOI. The Total area expected to be irrigated excludes the area to be implemented by the each district level because of unavailability of precise project list.

Table C.20 Potential Irrigation Area

(Unit: ha)

			Gulmi	Argha-khanchi	Kapil-vatsu	Rupan-dehi/1	Total
(1)	Existing Paddy Area		4,030	4,090	74,890	76,090	159,100
(2)	Irrigated Paddy Area Existing		1,840	2,260	25,320	31,540	60,960
		(%)	(46)	(55)	(31)	(37)	(35)
(3)	Rehabilitated		680	770	8,529	18,960	28,930
		(%)	(17)	(19)	(11)	(22)	(17)
(4)	= (2) + (3)		2,520	3,030	33,840	50,500	89,890
		(%)	(63)	(74)	(42)	(60)	(52)
(5)	Newly Developed		430	680	20,230	9,810	31,150
		(%)	(11)	(17)	(25)	(12)	(18)
(6)	Total = (4) + (5)		2,950	3,710	54,070	60,310	121,040
		(%)	(73)	(99)	(67)	(71)	(70)

/1 : The figure of Rupandehi includes all area of Rupandehi, out of the figure, the area of Marchawar Lift Irrigation Project is 5,770 ha.

3.2.2 Constraints for Development

Constraints hampering irrigation development clarified by the investigation can be summarized as follows:

(1) Constraints for Formulation and Design

(a) Large scale - topographic maps at 1:20,000 or 1:10,000, covering the study area, are not available at present, despite of that such large scale-maps are vital to find and identify projects and schemes of irrigation and other infrastructural developments including drinking water supply and rural road.

(b) Although the river flow is very limited, villagers in the upstream usually take water their convenience from the intakes constructed by them. The existing water rights particularly those of village panchayats have not been in control of the Government. Existence of powerful authority is required to control existing water rights.

(c) Jeepable access to and in the project or scheme area, particularly in the Gulmi and Arghakhanchi districts, is yet to be provided, though it is prerequisite for project identification, survey and study, and implementation, particularly transport of construction materials and commodities, because rural roads connecting between district center and village panchayats and among village panchayats are not constructed yet.

(d) System and organization for collecting information necessary for judging whether the projects and schemes demanded by village panchayats or villagers shall be taken up at district level or national level for proceeding the survey and study have not been established, though villagers' participation in the project and scheme from the formulation to the implementation is essential for their sustainability.

(e) Pre-feasibility and feasibility studies on the projects and schemes identified or proposed have not been performed timely because of shortage of technical staff and lack of budget at national and district levels.

(f) Feasibility study and detailed design on the project and scheme have not bee executed at the technical level required for receiving foreign aids, particularly financial aid.

(2) Constraints for Implementation

(a) Because of shortage of development budget at national level and and local level many projects are left for implementation, though their technical and economical viability has been assessed by the feasibility study. Besides, many on-going projects and schemes remain for completion owing to all-round allocation of the limited development budget at national and district levels.

(b) In case of large and medium scale-projects which have been implemented by the Department of Irrigation, Ministry of Water Resources, many ones have been in low progress of construction due to difficult management, lack of fund and shortage of technical manpower and construction equipment of the contractors, particularly local contractors.

(c) In case of minor schemes which are usually constructed by villagers' community, many ones are left for completion owing to shortage of construction materials such as cement, gabion wire, concrete pipe, corrugated pipe, PVC pipe, etc.

(d) Many existing minor schemes have not necessarily functioned because of technical defects, etc., resulting mainly from less construction supervision and technical guidance by district panchayat offices which have been suffered from shortage of technical staff and development budget.

(e) Many irrigation systems have not functioned well because of damages, sediment, erosion and scouring to the facilities and structures, affected mainly by less maintenance resulting from shortage of maintenance budget in case of national projects and technical defects including flood and land sliding damages in case of villagers' community schemes.

3.2.3 Potential Projects

Under such circumstances mentioned in the previous sections, the following irrigation projects and schemes are being studied or investigated.

(1) Kapilvastu District

1) DP Scheme

There are 282 minor irrigation schemes including rehabilitation of facilities, tubewell irrigation, and pond irrigation, demanded by village panchayats. However, all of them are yet to be formulated and identified in detail.

2) DOI Project

(a)	Jakjira Bandh	(700 ha)
(b)	Rajkudawa	(900 ha)
(c)	Bel Pond	(1,000 ha) (surveyed by JICA)
(d)	Bel Nadi	(400 ha)
(e)	Warkulpur	(1,600 ha)
(f)	Ghoraha Bandh	(860 ha)
(g)	Patna	(480 ha)
(h)	Charangwa	(320 ha)
(i)	Kanchaniya Bandh	(160 ha)
(j)	Renikuduwa	(under F/S by DOI)
(k)	Ghorahi Nadi	(2,500 ha)
(l)	Jabai and Banganga extension	

(m)	Phulika Irrigation	(1,500 ha)
(n)	Gotihawa - Mawaiya	(600 ha)
(o)	Dudara Nalla	(1,020 ha)
(p)	Lathahawa Bandh	(2,200 ha)
(q)	Jamuar Bandh	(1,560 ha)
(r)	Sisai River Bandh	(2,500 ha)
(s)	Marthi Bandh	(3,100 ha)
(t)	Patana	(540 ha)

(2) Rupandehi

1) DP Scheme

There are 304 minor irrigation schemes demanded by village panchayats, of which 43 schemes exist in the Marchawar area, an objective area of IRDP in Rupandehi district. However, all of them are yet to be formulated and identified in detail.

2) DOI Project

(a)	Madhuvani Village Panchayat	(1,050 ha)
(b)	Telar Nadi	(2,330 ha)
(c)	Shankarpur	(950 ha)
(d)	Chamkipur Bhalwari	(360 ha)
(e)	Kanchan Nadi	(gajedi ward No. 3) (230 ha)
(f)	Siyari Nadi	(2,500 ha, under F/S by DOI)
(g)	Tinau Khola	(4,000 ha)
(h)	Tubewell (to be formulated)	
(i)	Bhairahawa-Lumbini Groundwater Project Stage III (20,000 ha gross)	

(3) Gulmi

1) Project aided by European Economic Community (EEC)

(a) Bhanbhne Village Panchayat
(b) Bhuwanpan Village Panchayat
(c) Daudha Village Panchayat
(d) Gangha Village Panchayat
(e) Purtighat Village Panchayat

2) DP Scheme (for irrigation)

There are 44 minor irrigation schemes decided by District Panchayat Assembly, besides 48 minor irrigation schemes proposed by District Panchayat and 22 minor schemes proposed by village panchayats. However, all the schemes mentioned above are yet to be formulated and identified in detail.

3) DP Scheme (for river training)

(a)	Nisti Khola	15 sites
(b)	Chhall	3 sites
(c)	Pana Gad	2 sites
(d)	Daldi Khola	2 sites
(e)	Hugudi Khola	1 site
(f)	Jhenchi Khola	1 site
(g)	Badi Gad	1 site
(h)	Jumli Khola	1 site

4) DOI Project

(a)	Khadgakot (Baralwa)	(110 ha)
(b)	Ghamir Khola	(250 ha, under F/S by DOI)
(c)	Jhagdi Khola	(13 ha)
(d)	Paudi Arewa	(110 ha)
(e)	Chaldi	(100 ha)
(f)	Purti Ghat	(90 ha)
(g)	Sirseni	(140 ha)
(h)	Lahata	(40 ha)

(4) Arghakhanchi

1) Project aided by EEC

(a) Wangla Village Panchayat
(b) Argha Village Panchayat
(c) Rampat Village Panchayat
(d) Dhanachour Village Panchayat
(e) Thada Village Panchayat

2) DP Scheme (for irrigation)

There are 43 minor irrigation schemes demanded by village panchayats. However, all of them are yet to be formulated and identified in detail.

3) DP Scheme (for river training)

(a)	Khanchhi Khola	8 sites
(b)	Bangi Khola	5 sites
(c)	Sungure Khola	1 site
(d)	Paundi Khola	1 site

4) DOI Project

(a)	Chauwater	(70 ha)
(b)	Ringdi Wangla	(70 ha)
(c)	Kanchi Khola	(160 ha)
(d)	Durbangtar	(42 ha)
(e)	Durga Khola	(400 ha)
(f)	Kharijing Khola	(30 ha)
(g)	Kurlung Tar	(13 ha)
(h)	Milmile Khola (Madhura Khola)	(210 ha)
(i)	Bangi Khola	(47 ha)
(j)	Bajiyang Khola	(110 ha)
(k)	Pipalta Nerbi	(100 ha)

3.3 Master Plan of Irrigation Development

3.3.1 Selection of Projects

The following projects have been tentatively selected for the Master Plan Study for the year of 2005, taking the circumstances previously mentioned and realistic capacity to absorb into consideration. The projects are classified into (1) Central level project and (2) District level project according to its magnitude, etc. Some projects in the following list may be substituted in future by others according to the result of further study and change of circumstances.

(1) Central Level

The central level project will consist of construction of diversion weirs and intake, irrigation canals, and related structures. All necessary works for implementation such as field survey and design, construction works will be made under the Department of Irrigation. The total irrigation area will be about 8,890 ha so about 600 ha has to be implemented every year in the coming 15 years. Considering that the amount of fund required is quite large, some foreign aid will be indispensable for smooth implementation. The location of the projects selected are shown in Fig. C.7.

In the hill districts, sprinkler irrigation is proposed for effective use of water. The required material such as discharge pipe, riser pipe, sprinkler, etc. can be supplied to the farmers and then construction works will be done by the farmers.

1) Kapilvastu District

Name of Project	Panchayat	Command Area (ha)
a. Rajkudwa I.P.	Mahendrakot	2,400
b. Bel Nadi I.P.	Maharajgung	400
c. Khanchaniya Bandh I.P.	Lalpur	160
d. Phulika I.P.	Phulika	1,500
e. Patana I.P.	Patana	540
f. Jakjira Bandh I.P.	Patthardoiya	700
g. Charanga I.P.	Guganli	320
Total		6,020

2) Rupandehi District

Since the Marchawar area is developed by DOI under the finance of UNCDF, other central level project is not considered.

3) Gulmi District

Name of Project	Panchayat	Command Area (ha)
a. Ghamir Khola I.P.	Marbhung	250
b. Khadga Kot I.P.	Marbhung	110
c. Paudi Areba I.P.	Paudi Amarai	110
d. Chaldi Khola	Arje	100
e. Purti Ghat	Purtighat & Foxing	90
f. Sireseni	Sireseni	140
g. Lahata	Wangla	40
h. Sprinkler irrigation		300
Total		1,140

4) Arghakhanchi District

Name of Project	Panchayat	Command Area (ha)
a. Rindi Wangla I.P.	Wangla	70
b. Chauwatar I.P.	Thulo Pokhara	70
c. Mil Mile Khola I.P.	Wangla	220
d. Pipalta Nerbi I.P.	Kerunga	100
e. Rajvang Khola I.P.	Jukena & Thada	110
f. Durga Khola I.P.	Maidan	400
g. Khanchi Khola I.P.	Marpani	160
h. Sprinkler irrigation		600
Total		1,730

(2) District Level Project

There are many minor irrigation schemes including rehabilitation of facilities, tubewell irrigation, and pond irrigation, etc. proposed by District Panchayat Assembly and/or village panchayats. However, all the schemes mentioned above are yet to be formulated and identified in detail in terms of location, command area, necessary facilities, etc. Taking the capacity of absorb, one third of the proposed schemes are tentatively selected for the IRDP. The command area is estimated assuming that 100 ha for one scheme in the Terai plain and 20 ha for one in the Hill area. The Marchawar Lift Irrigation Project is being done by DOI. This project covers the most of the project area in the Marchawar area of Rupandehi district. So no district level project is proposed in this Master Plan. The necessary work for implementation such as identification of the location, field survey and design, and construction work will be conducted by the district panchayat office. People's participation will share large part of those works particularly construction work. However, the necessary materials for civil works such as cement and reinforcing steel, etc. and pumps if necessary, will be supplied by the local Government. The total irrigation area will be about 9,880 ha.

Name of District	Nos. of Scheme Proposed		Nos. of Scheme Selected	Command Area (ha)
Kapilvastu	282		90	9,000
Gulmi	114	Irrigation	30	600
	8	River training	2	
Arghakhanchi	43	Irrigation	14	280
	4	River training	1	
Total				9,880

(3) Total Irrigation Area

After the implementation of the Master Plan, the irrigation area in each district will be estimated as follows:

(Unit: ha)

Name of District	Existing	Increase	Total
Kapilvastu	25,320	15,020	40,340
Rupandehi (Marchawar)	100	5,770 *	5,870
Gulmi	1,840	1,110	2,950
Arghakhanchi	2,260	1,450	3,710
Total	29,520	23,350	52,870

*: Lift Irrigation Project

3.3.2 Priority Projects for Pre-F/S

The selected projects in the above section 4.3.2 are classified into several groups taking into such as capital cost required, location, etc. consideration. Then priority of the group are examined based on the following standard.

(a) An economic viability is reasonably expected.

(b) A technical study has been carried out thoroughly and a concrete idea of the project has been proposed in terms of location, magnitude and technical soundness, etc.

(c) An early implementation of the project is desired.

(d) Existing water right would not be affected by the implementation of the project.

(e) Adjustment and unification of water rights, which may take a long time, is not required for the implementation of the project.

The projects were examined by applying the criteria mentioned in the above paragraph as shown in Table C.21.

In the Table, a capital cost of each project is estimated based on the condition mentioned in the following chapter 6. Benefit of each project is estimated based on the conditions mentioned in the Annex A Agriculture and Agro-economy. Thus net present value of the cost and benefit is calculated at discount rate of 10%. The economic viability of each project is examined by Benefit minus Cost, Benefit by Cost and Internal Rate of Return. Household benefited by each project is estimated by applying average farm size estimated in the Annex A. concreteness and problem of water right of the project are judged by the survey team based upon the information, data and report supplied by the HMG/N.

As a result the following two projects were selected for priority projects.

1) Rajkudwa Irrigation, and Gorshinghiya and Rajpur Ponds Projects 2,400 ha
2) Banganga Irrigation Project

The detailed information and principal features of the projects are described in the following chapter 5.

4. IRRIGATION WATER REQUIREMENT

4.1 General

The crops proposed to be grown in the area are paddy and upland crops such as wheat, maize, coffee, groundnut, etc. The irrigation requirement for them is separately estimated based on the proposed cropping pattern. The irrigation water requirement consists of crop water requirement, ancillary water demands for respective crops and irrigation losses.

The irrigation water requirement for the crops is estimated on a monthly basis, using climatic data observed at meteorological station. Since climatic condition is different from the Terai plain and Hill area, the irrigation water requirement is estimated by the following procedure:

(1) Paddy

(a) Estimate of crop water requirement of paddy (CU) from reference crop evapotranspiration calculated by climatic data nd crop coefficients (Kc) varying with growth stages

(b) Estimate of percolation rate (P)

(c) Estimate of effective rainfall (EF)

(d) Estimate of other water requirement such as nursery (NW) and land preparation (PW)

(e) Estimate of net irrigation water requirement (NR)

$NR = CU + P - ER + NW + PW$

(f) Estimate of diversion water requirement (GR) based on divided by irrigation efficiency

(2) Upland Crops

(a) Estimate of crop water requirement (CU)

(b) Estimate of effective rainfall (EF)

(c) Estimate of pre-irrigation water requirement (Pr)

(d) Estimate of net irrigation water requirement (NR)

$NR = CU + PR - ER$

(e) Estimate of diversion water requirement (GR) based on divided by irrigation efficiency

4.2 Crop Water Requirement

4.2.1 Reference Crop Evapotranspiration

Crop water requirement is estimated as a product of reference crop evapotranspiration (ETo) and crop coefficient (Kc), which varies with crop growth stage. Because no useful data of the evapotranspiration is available, the reference crop evapotranspiration is calculated by the following Modified Penman Method recommended in "Crop Water Requirements, FAO Irrigation and Drainage Paper No. 24, 1977" since this method is generally accepted in the world as the most accurate formula.

Because meteorological characteristics are quite similar in Kapilvastu and Rupandehi Districts, the data at Bhairahawa (AGRI) meteorological station is used in the calculation for representative of the two Districts. The data at Khanchikot meteorological station is used for representative of Gulmi and Arghakhanchi Districts for the similar reason. The reference crop evapotranspiration calculated are shown in the following table.

Table C.22 Reference Crop Evapotranspiration

(Unit: mm/day)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
For Kapilvastu and Rupandehi Districts (Terai plain)												
2.1	3.0	4.9	7.0	8.0	6.8	5.3	5.0	4.3	3.9	3.0	2.0	4.3
For Gulmi and Arghakhanchi Districts (Hill area)												
2.1	3.4	5.0	6.7	6.0	5.5	4.6	4.3	4.0	2.0	2.6	2.2	4.0

4.2.2 Crop Coefficient

The proposed cropping pattern consists of rainy season paddy and upland crops. The crop coefficient varies with kind of crop, time of planting or sowing and stage of crop development. The determination of crop coefficient is made based on ths said FAO paper. Since no data on crop coefficient for respective kinds of vegetable crops are available, average of crop coefficient of cauliflower, onion, tomato and eggplant is employed representing that of vegetable crops. Crop coefficient curves are shown in Fig. C.8, and the estimated crop coefficients are shown in Fig. C.9.

4.2.3 Crop Water Requirement

Crop water requirement by each proposed crop is calculated by multiplying reference crop evapotranspiration by crop coefficient shown in Fig. C.9.

4.3 Percolation Rate

The soils in the project area have loamy to fine loam soil texture. Taking such soil texture for the project area into account, the percolation rate is assumed at 1 mm/day from July to November and 2 mm/day from December to June.

4.4 Other Water Requirement

4.4.1 Water Requirement for Nursery and Land Preparation for Paddy

The area required for nursery bed covers about 5% of the cropping area. Nurseries are operated in the same area and during the same period as land preparation. Accordingly, it can be assumed that nursery water requirement is covered with water to be supplied for land preparation. The field measurement on land preparation for paddy field in the project area has not yet been made so far.

The water requirement for land preparation consists of water equivalent to the difference in soil moisture before and after puddling, standing water required in soil surface, and evaporation and percolation losses from paddy field. The amount largely depends on such factors as soil properties, puddling method and period, groundwater table in the paddy field, etc. Taking into consideration these factors, the water requirement is assumed at 190 mm.

4.4.2 Water Requirement for Pre-irrigation for Upland Crops

Before planting the upland crops such as maize, wheat, mustard and mung bean, it is necessary to supply water for field, so-called pre-irrigation, in order to obtain the suitable moisture condition of field for germination of crop seeds. Assuming the soil depth, field capacity and soil moisture before pre-irrigation, water requirement for pre-irrigation is calculated to be 75 mm.

4.5 Effective Rainfall

Design rainfall for the estimate of water requirement is probable minimum rainfall with a 5-year return period. The effective rainfall is estimated to be 70% of the monthly rainfall in the paddy field. The effective rainfall in the upland crop field is estimated by applying the method proposed by USDA, SCS in 1969 recommended in the said FAO's paper. The results are shown in Table C.23.

4.6 Irrigation Efficiency

The losses of irrigation water generally consist of conveyance loss in the irrigation canal and application loss at the field. The conveyance loss depends on the soil condition on canal route, embankment materials of canal, canal lining, technical and managerial facilities of water control in the canals and skillness level on water management by the project staff. The application loss is primarily affected by method and control of operation, type of field soils, length of field canals, size of irrigation canal, etc.

(1) Conveyance Efficiency

As already mentioned, loamy to fine loamy soils are dominant in the project area. Topography is comparatively flat, though there exist partial rolling area. Taking into account such project conditions and the present conditions of existing canals which were constructed under the DOI, the conveyance efficiency is assumed at 80% for surface irrigation method and 95% for sprinkler irrigation method in which water is conveyed by pipe.

(2) Field Application Efficiency

The field application efficiency in paddy field is considered small, but that in upland crop irrigation is significant since it includes percolation, surface runoff, etc. Taking into account the soil characteristics, topography, climate, irrigation practices and experience, etc., the application efficiency is assumed to be 80% for paddy rice irrigation, 60% for upland crop irrigation by surface irrigation and 80% for sprinkler irrigation.

(3) Overall Irrigation Efficiency

Based on the above mentioned assumptions, an overall irrigation efficiency are estimated as follows:

For paddy cultivation	:	64%	Say 65%
For upland crop by surface irrigation	:	48%	Say 50%
For sprinkler irrigation	:	76%	Say 75%

4.7 Diversion Water Requirement

(1) Diversion Water Requirement

Diversion water requirement is estimated by dividing net irrigation water requirement by overall irrigation efficiency. The results are shown in Fig. C.9.

(2) Design Discharge of Irrigation Facilities

Based on the diversion water requirement calculated, the design discharge of irrigation facilities such as canals and related structures is determined at 1.5 lit/sec/ha for surface irrigation system and 0.8 lit/sec/ha for sprinkler irrigation system.

5. PRE-FEASIBILITY STUDY OF PRIORITY PROJECTS

5.1 Rajkudwa Irrigation, and Gorsinghiya and Rajpur Ponds Projects (A shortened name "Rajkudwa Irrigation Project")

(1) Rajkudwa Irrigation

This project located in the Mahendrakot Panchayat in Kapilvastu District depends upon the irrigation water resources of the Kondre and Rajkudwa rivers which originate from the southern slope of the Churia hills. The command area will be about 900 ha. Basic idea of the project was identified and the construction works have started since the last fiscal year (1988/89). Because only one tenth of total construction costs have been allocated in one year, it will take more than ten years to complete the construction works as a whole. The headworks will be located at the junction of the two rivers and no water right appears to exist so far. However, headworks and main canal are not appeared to be properly designed. Secondary and tertiary canals required for adequate water distribution are not designed.

(2) Gorsinghiya and Rajpur Ponds Project

Eight ponds for irrigation purposes are presently located in the Gorsinghiya and Rajpur villages. It is planned to enlarge these ponds and supply water through the canal proposed in the Rajkudwa Irrigation Project so as to stabilize irrigation in the rainy season and to retain more irrigation water during the dry seasons for about 1,500 ha.

(3) Component of the Project

The component of the project is comprised of design and construction of new diversion weir, irrigation canals and related facilities, rehabilitation and enlargement of existing ponds in the Gorshingiya and Rajipur Panchayats. Assuming that the project is transferred from district level to central level and that a certain amount of foreign aid is provided, all necessary works such as review of existing plans and designs, and construction works will be completed within three years. According to the basic design made by the district engineer office so far, the salient features of the Rajkudwa Irrigation Project are as follows: The location of the project is shown in Fig. C.7.

(4) Pre-requisite for Implementation

A topographic map with a scale of 1 to 10,000 or 1 to 20,000 has to be prepared for a gross area of about 120 km^2. Because the definite plan of the project has not yet identified from both technical and economical viewpoints, a feasibility study has to be made based on the map and field investigation. The study includes (a) identification of irrigable area, canals and other irrigation facilities, (b) hydrological study on the rivers, (c) preliminary design of facilities, (d) cost estimate and project evaluation.

The detailed design and tender will follow after the feasibility study.

(5) Principal Features

Command Area	:	900 + 1,500 = 2,400 ha
Diversion Weir and Intake (Fig. C.10)		
Type of weir	:	Concrete Gravity Type
Crest length	:	23.0 m
Crest height	:	2.0 m
Intake discharge	:	3.0 m^3/sec
Settling Basin (Fig. C.11)		
Length	:	40.0 m
Water Depth	:	3.0 m
Main Canal (Fig. C.12)		
Rectangle Conduit Type Section (Free flow)	:	3.0 km
Discharge	:	3.0 m^3/sec
Base width	:	2.5 m
Water depth	:	2.3 m
Open Trapezoidal Earthen Type Section	:	14.0 km
Discharge	:	3.0 m^3/sec - 1.5 m^3/sec
Base width	:	1.6 m - 1.5 m
Water depth	:	1.6 m - 1.4 m
Ponds	:	8 nos.
Base length	:	630 m x 630 m
Height	:	3 m
Effective storage capacity	:	992,250 m^3 per each

5.2 Sprinkler Irrigation Project

Although the sprinkler irrigation in the Hill area is classified into third priority in the Master Plan Study in the previous section 3.3, the result of preliminary study is described in this section.

Sprinkler irrigation has been recently introduced in the Hill area in Nepal under the Department of Irrigation or other agency. Under the finance of Agricultural Development Bank, Nepal (ADB/N) the loan included costs for nozzles riser, pipe, costs for construction of water tank and pipe line, etc. The nozzles are usually provided by the ADB/N to the farmers concerned. Main crop is coffee and citrus. Groundnut, papaya, pineapple, ipilipil (fodder), pear, and banana are also cultivated in mixed condition. Water is taken in the mountain streams. If one stream has not sufficient water, water is collected from the several streams. The water is conveyed by pipe by gravity pressure to the farm. The energy head of water is generally at about 30 m to 50 m.

A typical layout of the sprinkler system is planned for future implementation. It will consist of one to three sets of intakes and settling basins, delivery pipe, a farm pond, distribution pipe, valves, and sprinklers as shown in Fig. C.13. A numbers of intake and settling basin is depend on the quantity of water available in one stream and command area to be irrigated. Principal feature of the sprinkler system are as follows:

Typical Command Area (7 Rotation Blocks) : 5 ha

Intake Structures with Settling Basin : 3 nos.

Water Conveyance System

Pipeline : Dia. 50 mm, High-density Polyethylene Pipe, Length 1,000 m, Discharge 2 lit./sec

Pipeline : Dia. 60 mm, High-density Polyethylene Pipe, Length 100 m, Discharge 4 lit./sec

Distribution System

Pipeline : Dia. 120 mm, High-density Polyethylene Pipe, Length 2,060 m, Discharge 7.54 lit./sec

Farm Pond : 1 no.

Base Width	:	15 m x 15 m
Height	:	4 m
Effective Storage Capacity	:	675 m3

Sprinkler : 10 nos.

Sprayable Diameter	:	32.0 m
Discharge	:	0.76 lit./sec per each

6. COST ESTIMATE AND IMPLEMENTATION PLAN

6.1 Basic Conditions

(1) Mode of Construction

Considering the scale of each project, the construction works will be executed on the local competitive bidding. The construction machinery and equipment required for the construction will be provided by the contractors themselves.

(2) Price Level, Currency and Exchange Rate

The price level of cost estimate is assumed as of the middle of 1989. The exchange rate between US$ and NRs. is assumed at current official rate in October.

US$ 1.00 = 28.00 NRs. = Yen 141.00

(3) Price Escalation

The price escalation factor is assumed at 12% for local currency and 3.5% for foreign currency by referencing the those applied in the recent irrigation project, road project such as the East Rapti Irrigation Project, Narayani Zone Irrigation Project, etc.

Year	Escalation in %	
	Local	Foreign
1986	10.0	12.0
1987	12.0	3.0
1988	12.0	1.0
1989	12.0	1.0
1990	12.0	1.0
After 1991	12.0	3.5

(4) Physical Contingency

The physical contingency shall be assumed at 10% of the sum of direct and indirect construction cost.

(5) Tax

The construction machineries, equipment and materials to be imported from abroad are to be exempted from the tax.

(6) Unit Price

The unit prices of major work item are estimated synthetically on the basis of the prices obtained from the recent irrigation project, road project and water supply project in Nepal and the prevailing prices of similar works in Nepal. The price escalation factors are considered for adjusting the prices to 1989 level prices.

The recent situation caused by unexpected change of relation between Nepal and India is not considered for the estimate of this time, as the situation is not settled yet.

(7) Lump Sum

Some works which are hardly estimated by unit price at present study are estimated by lump sum basis taking into consideration other recent irrigation projects in Nepal.

(8) Construction Method

The construction works will be carried by mainly manpower except some heavy works such as sheet piling, excavation in the water, road excavation, etc.

6.2 Project Cost of the Master Plan

The total project cost of irrigation development in the Master Plan is estimated as follows:

(Unit: million NRs)

Construction Cost	
Central Level	1,335
District Level	194
Sub-total	1,529
Price Escalation	1,533
Total	3,062

The construction cost of each district is shown in Table C.24. The annual disbursement schedule of each district is shown in Table C.25.

6.3 Project Cost of the Priority Projects

The project cost of the priority projects are estimated as shown in Table C.26 to Table C.28 and summarized as follows:

(Unit: million NRs.)

	Rajkudwa Project
Construction Cost	281.4
Price Escalation	41.4
Total	322.8

The cost of mapping and feasibility study for the Rajkudwa project is not included.

The construction cost of sprinkler irrigation system is estimated at NRs. 484,100 per ha as shown in Table C.28.

6.4 Operation and Maintenance Cost

The annual costs for operation and maintenance include the salaries of technical and administrative staff; repair and maintenance costs for O&M equipment; fuel cost for O&M equipment, electric charge for tubewell pump operation; repair and maintenance for tubewell pumps; labour cost for repair and maintenance of project facilities and materials costs for repair and maintenance of project facilities. In irrigation, most of the O&M cost will be bared by the farmers. The annual operation and maintenance cost for each component is estimated as based on those in other irrigation projects in Nepal.

Table C.29 Annual Operation and Maintenance Cost

		Cost per ha (NRs.)	Command Area (ha)	Amount (million NRs.)
(1)	Central Level			
	Terai Area	400	6,020	2.4
	Hill Area			
	Surface irrigation	800	1,970	1.6
	Sprinkler irrigation	1,600	900	1.4
	Sub-total		11,760	5.4
(2)	District Level			
	Terai Area	140	9,000	1.3
	Hill Area	260	880	0.2
	Sub-total			1.5
	Total			6.9

Since the salaries of technical and administrative staff of the District Level project will be born by the Government budget, the O&M cost of the District Level is assumed one third of those of Central Level project.

6.5 Implementation Program

(1) Central Level Project

Since the central level project requires huge amount of capital cost and have technical difficulties, some foreign aid for finance and technical assistance are indispensable for smooth implementation. The project will be implemented every five year as shown in Fig. C.14. The implementation schedule of the priority project is shown in Fig. C.15. The Department of Irrigation in Ministry of Water Resources may have an important role on the project formulation, preparation of necessary data for foreign agency, project design and implementation.

The sprinkler irrigation will be implemented 20 ha in Gulmi and 40 ha in Arghakhanchi districts every year. The major materials for sprinkler irrigation such as pipe, sprinkler, valve, etc. will be supplied by the Government to the farmers. Civil works such as water intake and settling basin, farm pond, pipe line will be constructed by local tender or farmers themselves.

(2) District Level Project

The irrigation development of district level project will be implemented 600 ha in Kapilvastu, 40 ha in Gulmi, 20 ha in Arghakhandu every year.

To implement the district level project, the following works have to be made by the district office and/or villagers community:

(a) Selection of the project to be implemented every year

(b) Identification of the projects selected in terms of location, scale of the project, work quantities, construction method, etc.

(c) Collect data necessary for establishment of procurement plan

(d) Distribution of materials procured

(e) Most of the construction works will be conducted by villagers, however, arrangement and control of construction works have to be done by the engineers in the district office

6.6 Organization for Project Implementation

In order to proceed with construction of the Project facilities, the following works will have to be executed by the Government of Nepal:

- Mapping and feasibility study, if necessary
- Detailed design including preparation of tender documents
- Prequalification and tendering
- Land acquisition
- Construction supervision

For smooth execution of the above works, an executing organization is proposed which is tentatively called "the Project office" under the Department of Irrigation (DOI). To coordinate, guide and assist the Project office in the implementation, a coordination committee is also proposed under the DOI. The committee will consist of representatives of authorities concerned such as high-ranking officers of Western Region administration, and Districts offices concerned. One director of the Project office will be appointed by the DOI, and he will be responsible for all the operation and management of the office. At the construction stage, the office will have five sections: (i) design section, (ii) construction section, (iii) equipment section, (iv) accounting section and (v) administration section. The design and construction sections will have three sub-sections, respectively (i) main facilities, (ii) rural infrastructures and (iii) on-farm work.

6.7 Organization for Operation and Maintenance

After completion of Project construction, the Project facilities will be transferred to the District offices, and the Project office will be put under the authority of the District engineer. DOI will be a member of the coordination committee, and will assist and collaborate with the Project office in the operation and maintenance of the Project facilities. The director of the Project office will be appointed by the District office. The Project office will have the following operation and maintenance responsibilities.

- Planning of the irrigation schedule
- Monitoring and record-keeping of meteorological data
- Operation of irrigation water supply
- Day-to-day administration relating to water management according to the operation rule
- Monitoring of irrigation water supply
- Maintenance and repair of the irrigation and drainage facilities
- Operation and maintenance of the equipment and machinery
- Technical guidance and training for farmers in water management
- Farming guidance for farmers
- Operation and maintenance of rural infrastructures

In order to carry out the above works, the Project office will be organized into four sections, namely (i) operation section, (ii) maintenance section, (iii) accounting section and (iv) administration section. The operation section will have four sub-sections: (i) monitoring and planning, (ii) irrigation operation, (iii) rural infrastructures, and (iv) training and guidance. The maintenance section will have two sub-sections: (i) repair and maintenance, and (ii) equipment and store.

After the farmers' level, irrigation water users' associations will have to be organized on a tertiary canal basis to manage water supply and maintain the on-farm facilities under the technical guidance of the Project office.