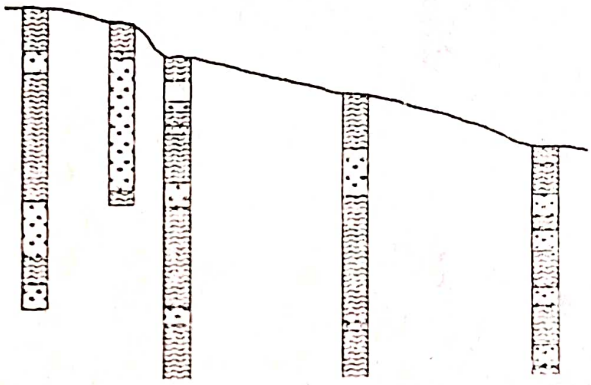
UNITED NATIONS DEVELOPMENT PROGRAMME
AND
HIS MAJESTY's GOVERNMENT OF NEPAL
NEP/86/025

SHALLOW GROUND WATER INVESTIGATIONS IN TERAI

RUPANDEHI

SHALLOW WELLS DRILLING, TESTING AND MONITORING IN 1988/89

BASIC DOCUMENTATION AND PRELIMINARY INTERPRETATION



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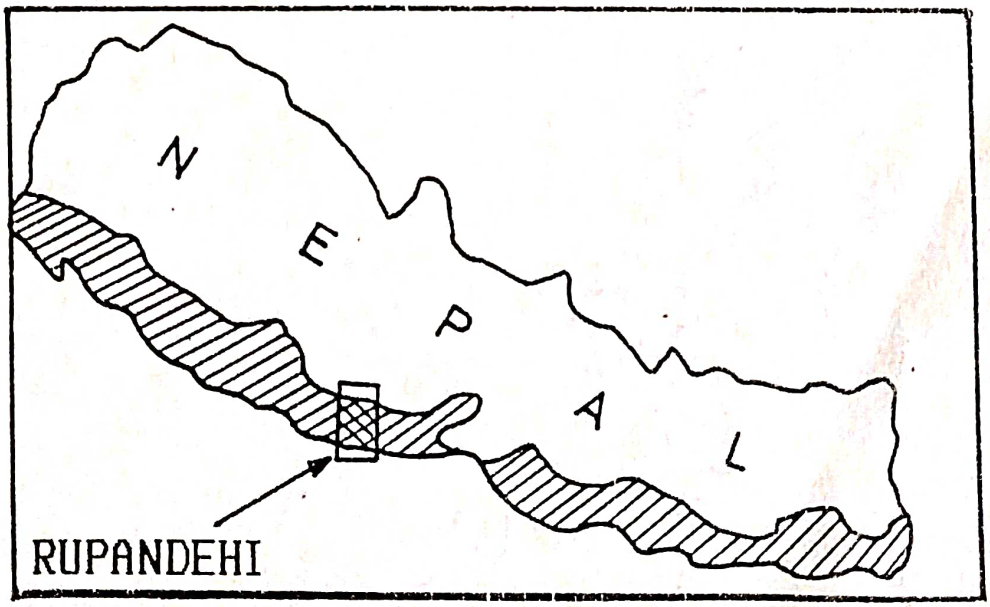

KATHMANDU, SEPTEMBER 1989

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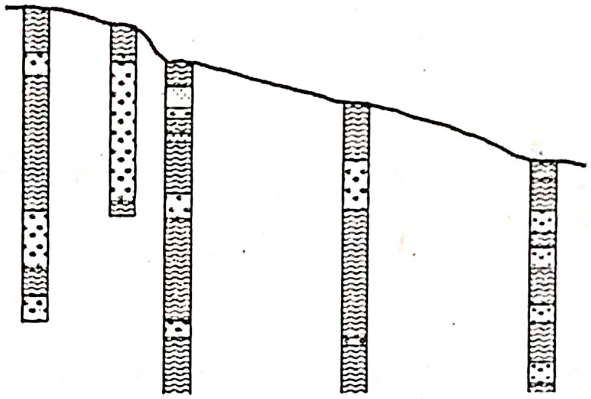

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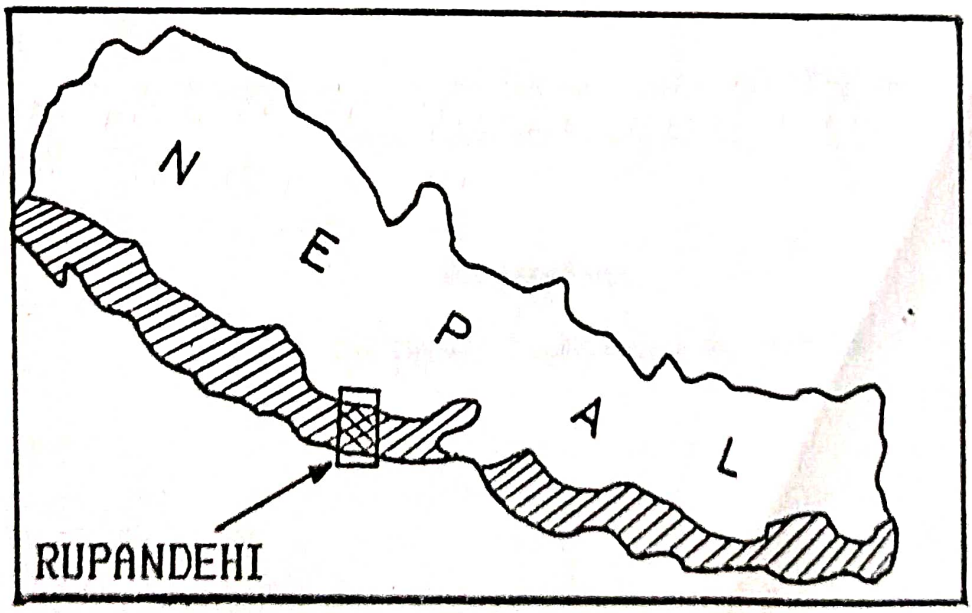

KATHMANDU, SEPTEMBER 1989

UNITED NATIONS DEVELOPMENT PROGRAMME

AND

HIS MAJESTY'S GOVERNMENT OF NEPAL

PROJECT NEP/86/025

SHALLOW GROUND WATER INVESTIGATIONS IN TERAI

TECHNICAL REPORT NO. 14

RUPANDEHI DISTRICT

SHALLOW WELLS DRILLING, TESTING AND MONITORING IN 1987/89

BASIC DOCUMENTATION AND PRELIMINARY INTERPRETATION

Executing Agency: United Nations Department of Technical Co-operation for Development

Prepared by:

Suresh Raj Uprety, Geohydrologist, GWRDB

KATHMANDU, SEPTEMBER 1989

EXECUTIVE SUMMARY

The objective of this report is to present technical information on the occurrence of shallow ground water in Rupandehi district. It is presented in a form of a basic documentation with some preliminary interpretation.

The drilling program, which was formulated about a year ago for the purpose of investigating shallow aquifer in Rupandehi district, produced twenty six holes with the total drilling metrage of 1226 m. The average depth of newly completed wells is 47 m. Considering the lithology of shallow ground water system, this depth is probably adequate for the project purpose. Out of 26 drilled wells, 17 wells were constructed by drilling rig, and nine wells manually.

The average percentage of permeable materials (sand and/or gravel) within 47 m depth is about 38% in Rupandehi district. This means that almost at any depth interval one may expect about 4 meters in each 10 drilled meters. The percentage is somewhat higher in Bhairawa Lumbini Ground Water Project (BLGWP) area. Analysis of lithological logs suggest that the north-eastern part of the district has more than 20 m permeable materials within the shallow depth. A lithological data base was created with 70 wells, including all new project wells, earlier GWRDB shallow wells, selected wells from water-supply drilling program by Japanese Red Cross Society wells, and shallow portion of some deep wells from the Bhairawa-Lumbini ground water irrigation project. The interpretation of lithology did not prove the existence of a continuous and thick impermeable clay layer that might effectively cut off the deep aquifer currently developed at BLGWP area from the shallow aquifer. On the contrary the proportion of permeable layers in overall drilling depth gradually reduces from 42% in upper 10 meters to 38% at the depth of 47 m, and to 32% at the depth over 200 m.

The transmissivity distribution is shown in a map which was created from pumping test results. The central-north part has very high transmissivity for a shallow aquifer, more than 2000 m^2/day, reaching as high as 16,000 m^2/day. This is the area which coincides with Stage I of Bhairawa-Lumbini ground water project, and extends to Butwal including the whole Bhabar zone. However, in peripheral parts toward south, north-east, south-east, and west-central the transmissivity is drastically reduced to several hundred square meters per day only.

In most of the area the levels in driest months (May-June) are within 5.0 m below the land surface, with some exceptions. This is favorable for local pumping from shallow aquifer using widely available cetrifugal pumps with suction head limited to about 7 meters. The rise of shallow levels from pre-monsoon to post- monsoon period (May-June to September 1989) is in most of the area between 0.2 and 4.4 m. Water levels start rising in the month of June as a direct response to June rainfall. The near- maximum water levels are normally established in the month of September. There is almost no time lag in the response of levels to rainfall at the beginning of rainy season, but near its end the time lag is normally one month. This is to say that maximum levels are in September/October, and minimum levels normally in May.

Preliminary evaluation of shallow ground water balance as presented in this report concluded the following.

(1) The recharge comes from local infiltration of rainfall everywhere where more or less permeable surface permits. The percentage of infiltration may be high. But there may be plenty of

rejected recharge in monsoon season because of oversaturation of soil immediately underlying the land surface. This is certainly true in the lower part where water table in the monsoon season comes very close to the ground surface.

(2) The outflow of shallow ground water is mostly across the border into neighboring India. Annual outflow into India across the border is estimated at about 8 MCM (million cubic meters). This is a small fraction of potential annual recharge from infiltrated rainfall.

(3) Two different approaches produce the annual recharge to shallow aquifer between 294 and 375 MCM, considering the area of 1140 km^2 and average annual rainfall of 1900 mm. The permeable Bhabar zone covers at least 100 km^2. Bhabar area is primary source of recharge to both shallow and deep aquifers. The difference between hypothetic recharge of over 300 MCM and outflow into India of only 8 MCM is discharged through evaporation process (dominantly); outflow into the Tinau, Dano, and other rivers; by withdrawals from dug and drilled wells (minor component at present). Likewise, there may be plenty of water leaking vertically downward and recharging deep aquifer, wherever the head differential sign indicates so.

The water that is lost through evaporation process, wherever water table comes to within 2 or 3 meters from land surface, can be salvaged by carefully planned exploitation, provided that the lithology of shallow aquifer (that is its thickness and transmissivity) permits ground water development by pumping.

On the basis of the presented information, an area of about 400 km^2 located in central-north, partly north-western part, of the district, is declared as most feasible for large-scale shallow ground water development. Without quantifying tools, such as models, it is difficult to interpret the area in terms of quantitative parameters for large-scale development.

With an individual well discharging 12 l/sec throughout an average pumping season of 120 days, with each well pumping for about 10 hours a day, about 1350 shallow tube wells might be needed to irrigate about 8100 hectares. Each well can irrigate on average 6 hectares, provided that the agricultural demand is 8000 m^3/season/ha. In this development scheme, estimated recharge is about 132 MCM, out of which only 50% is considered to be utilized. The area of 8100 ha that can be irrigated by shallow wells is about one fifth of the total area. This area has transmissivity in excess of 1000 m^2/day, aquifer is more than 13 m thick, and water level most of the time in the year is within 3 m depth. The average depth of drilling and development of shallow aquifer could be between 45 and 50 meters.

In the rest of the district area, individual wells for domestic water use or village water supply, including some small-scale irrigation, can be constructed in places where water level is closer to the land surface and the transmissivity is relatively higher.

A multi-layered mathematical model can provide quantitative answers about the hydraulic connection between shallow and deep aquifers, and can forecast the impact and consequences of future extensive development of either of aquifers. Such a model is long time overdue considering the plan to extend the current irrigation system of Bhairawa-Lumbini project into Stage III. The modeling work in such a multi-layered system is a serious task, which may take several months, but the benefits could be immense.

EARLIER TECHNICAL REPORTS

1. Bhairawa-Lumbini Ground Water Irrigation System Preliminary Mathematical Modelling. May 1988.

2. Shallow Ground Water Level Fluctuations in the Terai in 1987. Preliminary Report. May 1988.

3. **RAUTAHAT DISTRICT.** Shallow Wells Drilling, Testing and Monitoring in 1987/88. Basic Documentation and Preliminary Interpretation. November 1988.

4. **RAUTAHAT DISTRICT.** Mathematical Model of Shallow Ground Water System. December 1988.

5. **NAWALPARASI (WEST).** Shallow Wells Drilling, Testing and Monitoring in 1987/88. Basic Documentation and Preliminary Interpretation. March 1989.

6. **NAWALPARASI (WEST).** Mathematical Model of Shallow Ground Water System. March 1989.

7. **KAPILVASTU DISTRICT.** Shallow Wells Drilling, Testing and Monitoring in 1987-89. Basic Documentation and Preliminary Interpretation. June 1989.

8. **DANG VALLEY.** Shallow Wells Drilling, Testing and Monitoring in 1987-89. Basic Documentation and Preliminary Interpretation. June 1989.

9. **DEUKHURI VALLEY.** Shallow Wells Drilling, Testing and Monitoring in 1987-89. Basic Documentation and Preliminary Interpretation. June 1989.

10. **SUNSARI DISTRICT.** Shallow Wells Drilling, Testing and Monitoring in 1987-89. Basic Documentation and Preliminary Interpretation. June 1989.

11. **RUPANDEHI DISTRICT.** Deep Tube Wells Drilling, Testing and Monitoring in 1969-89. Basic Documentation and Preliminary Interpretation. September 1989.

12. **MORANG DISTRICT.** Shallow Wells Drilling, Testing and Monitoring in 1987-89. Basic Documentation and Preliminary Interpretation. September 1989.

13. Shallow Water Level Fluctuation Maps of Terai 1987-89. September 1989.

ABBREVIATIONS:

UN/DTCD	- United Nations Department of Technical Co-operation for Development
UNDP	- United Nations Development Programme
USAID	- United States Agency for International Development
GWRDB	- Ground Water Resources Development Board
BLGWP	- Bhairahawa Lumbini Ground Water Project
GDC	- Groundwater Development Consultants (International) Ltd.
ADB	- Asian Development Bank
STW	- Shallow Tube Well
DTW	- Deep Tube Well
UN	- UNDP/NEP/86/025 Wells
US	- USAID Wells
BL I	- BLGWP First Stage Wells
BL II	- BLGWP Second Stage Wells
JR	- Japanese Red Cross Wells
MCM	- Million Cubic Meters

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- 5.7 UN 10 - Bhalwari
- 5.8 UN 11 - Makrahar
- 5.9 UN 12 - Panani
- 5.10 UN 13 - Parasi Jhunga
- 5.11 UN 14 - Sikthan
- 5.12 UN 22 - Siso Semara
- 5.13 UN 23 - Ramnagar
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1. BACKGROUND INFORMATION

1.1. NEP/86/025 Project Document Details

The project NEP/86/025 - Shallow Ground Water Investigations in the Terai - is executed by the United Nations Department of Technical Co-operation for Development. It is designed as a four- year project primarily oriented to field-data collection, establishment of ground water data base, and to assessment of development potentials of shallow aquifers all over the Terai. The government counterpart agency is the Ground Water Resources Development Board (GWRDB) of the Department of Irrigation of the Ministry of Water Resources. The project's activities started in June 1987.

The immediate objectives of the project NEP/86/025 are the following.

(1) To generate technical information on the occurrence and potential of shallow ground water resources in the Terai.

(2) To obtain the information regarding drilling and construction of shallow tube wells.

(3) To enhance the capacity of the GWRDB with regard to exploration, assessment and development of ground water.

The following project outputs are anticipated:

(a) Computerized data base with about 2000 shallow water points from all over the Terai. Information on lithology, hydrogeological parameters, water use, etc.

(b) Maps of pre-monsoon (maximum) and post-monsoon (minimum) water depths expressed in relative depths from the land surface and in absolute elevations above mean sea level.

(c) Water level graphs (hydrographs) from selected observation points in a minimum period of one year.

(d) Reports on mathematical modelling.

(e) Report on drilling methods and results in shallow water well drilling in the Terai.

1.2. Basis for this Report

This report is based on the following:

(a) NEP/86/025 project wells (for ease of reference called "project" wells) - 26 newly drilled shallow wells between January and July 1989.

(b) Some of the wells drilled for Ground Water Resources Investigations in Lumbini Terai by USAID/GWRDB in 1971/72.

(c) Some of the wells drilled for Ground Water Irrigation in Lumbini Terai by BLGWP under GWRDB from 1978 to 1989.

(d) Some of the wells drilled by Japanese Red Cross for drinking water supply in Rupandehi district in 1983/84.

(e) Pumping tests conducted in project wells in 1989.

(f) Pumping tests conducted in USAID shallow wells in 1972.

(g) Water level observations since May 1987.

(h) Groundwater Resources Development Strategies for Irrigation. Groundwater Development Consultants (UK), Ltd. 1987.

(i) Duba, D. 1982. Groundwater Resources in the Terai of Nepal.

(j) Tillson, D. 1985. Hydrogeological Technical Assistance to the Agricultural Development Bank of Nepal. ADB-UNDP report.

(k) Several Mission Reports by the Chief Consultant in this project.

(l) Technical Reports No. 11 and 13 of this project.

1.3. Location, Size, Climate

Rupandehi district belongs to the Western Region (in addition to Kapilvastu and Nawalparasi districts). The district's Terai part occupies an area of 1140 km^2. According to Tillson (1985), a total of 810 km^2 of the Rupandehi Terai is suitable for irrigation by using 3807 numbers of 12 l/s capacity shallow tube wells. The location of Rupandehi district within Nepal is shown in Figure 1. For the purpose of studying the shallow ground water system of the Terai, the contour line 150 m is considered to be the physical end of the Terai's Quaternary sediments. The main characteristics of climate in Rupandehi district, as well as in the whole Terai, is monsoon rainfall which occurs between June and September and which delivers an average of 85% of the total annual rainfall. For the purpose of this report the data collected in two rainfall stations: Butwal and Bhairahawa Airport (Figure 1) are used. It is to be understood that the data are not officially cleared by the HMG Meteorological Service, but rather used in a draft form as an indication for the correlation between shallow water level fluctuation and the rainfall. Although the Terai of Nepal is in subtropical zone, the mean monthly temperature reaches a low of about 15° C in January compared to a high of about 31° C in June. Evolution of shallow ground water levels is heavily dependent on the distribution of rainfall. Most of the recharge to shallow aquifers comes from fan deposits near the Siwalik hills and mountains. The amounts of rainfall in the years 1987, 1988 and 1989 will be discussed in Section 4.2. The mean annual rainfall is close to 1900 mm and pan evaporation is about 1500 mm.

Average monthly rainfall exceeds average evapotranspiration during only 4 months, June to September. Because of the large moisture deficit during the remaining months a second rice crop cannot be grown under normal conditions. The low winter temperatures preclude a third rice crop even with the addition of irrigation.

The major river in this district is Tinau which flows diagonally, from northeast to southwest, in the central part of the district. Unfortunately, there is no gauging station in this river. Therefore, its flow rate is not known.

2. PROJECT ACTIVITIES IN 1987-89

2.1. Drilling

Out of the total planned scope of drilling within this project, which amounts to about 200 shallow wells for the whole Terai, the program of drilling for Rupandehi district was prepared about a year ago providing for drilling of 31 wells with an average drilling depth of 50 m. The total drilling metrage in Rupandehi was estimated at 1550 m. Here below the planned and actual implementation is shown:

Planned: 31 STW Total drilling metrage: 1550 m
Actual: 26 STW Total drilling metrage: 1226 m

Both with respect to number of drilled wells and total drilled metrage, the implementation was below what had been programmed. The implementation compared to the design is illustrated in Figures 2 and 3. The locations of "project" wells areshown in Appendix 1 and a map showing locations of all wells considered for the purpose of this report which includes selected USAID, BLGWP and Japanese Red Cross wells is presented in Appendix 1A. Seventy lithological logs with other well construction data are appended in the group of Appendices 3 (3/1 through 3/70). Lithological cross-sections are presented in Appendices 4 (4/2 through 4/10).

The actual number of wells in Rupandehi district drilled by this project is 26. Out of those, 17 (planned 11) were constructed by rig machine and 9 (planned 20) manually. None of them were abandoned. Average depth of the wells was 47 m.

Table 1. presents the most pertinent data on the drilling of project wells and other selected wells as well.

TABLE 1

NO.	X	Y	LOCATION	Z (m)	DEPTH (m)	COMMENTS (water level from GL)
1	736875	3055625	Madangaj	116.4	46.0	Completed -2.33
2	738625	3060750	Manoharpur	145.1	45.0	Completed -4.65
3	730625	3061750	Baksad	121.0	36.0	Completed +2.10
4	723000	3060750	Gajedi	122.5	52.7	Completed +4.03
5	722125	3066625	Saljhandi	152.4	34.0	Completed -5.39
6	731250	3064500	Murgiya	141.7	48.0	Completed -1.02
7	737000	3065000	Rani Bagiya	146.3	36.0	Completed +0.30
8	750750	3061250	Bhaluhi	130.2	43.0	Completed -6.78
9	745625	3060000	Premnagar	143.3	42.0	Completed +0.40
10	745750	3055000	Bhalwari	121.0	42.3	Completed +0.40
11	748625	3055500	Makrahar	123.1	47.3	Completed +0.40
12	746875	3045000	Panani	108.2	67.0	Completed +0.28
13	752000	3045000	Parasi Jhunga	109.7	52.0	Completed -2.68
14	750375	3050375	Sikthan	117.6	54.6	Completed -4.47
15	731125	3055500	Gurauliya	114.0	43.0	Completed -
16	723750	3055875	Rudrapur	109.7	58.0	Completed -2.32
17	730250	3051250	Surawal	106.4	50.0	Completed -2.6
18	726500	3049375	Gidahiya	105.2	48.8	Completed -

19	724500	3045375	Naukadiha	103.6	46.0	Completed	—
20	745250	3050250	Khunsa	116.4	54.6	Completed	—
21	738125	3045750	Hati Bangai	106.7	55.0	Completed	-1.95
22	731500	3028250	Siso Semara	90.5	36.6	Completed	-1.8
23	731125	3034375	Ramnagar	96.0	45.7	Completed	— 3.17
24	737375	3034875	Bogari	97.2	45.7	Completed	-1.29
25	731125	3029625	Bichawapur	92.1	51.0	Completed	-1.6
26	724250	3040000	Padariya	95.1	43.0	Completed	—
27	752750	3041250	Vishnupura	103.6	72.9	Completed	
28	752375	3048500	Belahia	113.7	80.5	Completed	- 2.7
29	752000	3052375	Petrabania	119.8	118.0	Abandoned	
30	755875	3059250	Kerwani	134.7	152.0	Completed	
31	738375	3042500	Paklihawa	104.3	83.2	Completed	
32	741125	3043875	BWA Water Tank	109.7	67.1	Completed	
33	742000	3046500	Agr. Res. Farm	111.3	54.6	Completed	
34	742625	3048500	Govt. Fish Farm	115.8	54.9	Completed	
35	743250	3053375	Manglapur	121.9	170.7	Completed	
36	743125	3056625	Manigram	128.6	48.2	Completed	
37	742875	3061875	Jogikuti	153.9	45.7	Completed	
38	743375	3064000	Butwal	174.0	90.2	Completed	
39	727250	3029375	Jigna	93.0	289.6	Abandoned	
40	730500	3026500	Sonbarsa	89.3	100.6	Abandoned	
41	736375	3032750	Bogri	96.9	38.1	Completed	
42	731500	3041750	Semri	100.6	153.3	Completed	- 5.95
43	732625	3047250	Chilia	109.7	147.2	Completed	
44	733375	3048250	Baidauli	112.8	59.1	Completed	
45	732375	3057625	Bhujauli	121.0	99.1	Completed	
46	726750	3039750	Mahajidia	98.8	152.4	Abandoned	
47	720625	3042125	Mughla	94.5	164.3	Completed	
48	721625	3048500	Sarahawa	100.6	152.4	Completed	
49	722125	3056750	Asnia	115.8	122.8	Completed	
50	740875	3055500	E. Semra	123.1	141.0	Completed	
51	740250	3058125	Dubauliya	127.6	140.0	Completed	
52	736750	3058375	E. Kewalpur	123.9	137.5	Completed	
53	738125	3052375	Kanari	115.5	164.0	Completed	
54	734000	3052125	Dayanagar	112.6	164.0	Completed	
55	748500	3052750	Barauliya	116.9	169.0	Completed	
56	729250	3048250	N. Ahirauli	100.7	163.0	Completed	
57	726375	3043750	W. Bharaulia	98.5	198.0	Completed	
58	728375	3045750	Sonbarsa	94.2	206.0	Completed	
59	723750	3052875	Sihawa	101.9	124.0	Completed	
60	721500	3046500	Masina	102.1	28.0	Completed	
61	732750	3037875	Majgaw	98.1	19.0	Completed	
62	729750	3065250	Dudharchh	138.7	35.0	Completed	
63	756500	3061500	Khaireni	146.6	10.0	Completed	
64	724250	3063875	Bankatti	140.2	35.0	Completed	
65	734625	3062125	Narenapur	121.9	25.0	Completed	
66	750375	3057625	Mirgauli	128.0	26.0	Completed	
67	721625	3038125	Nandnagar	95.4	34.0	Completed	
68	724500	3035625	Ardola	93.9	32.0	Completed	
69	729625	3032125	Mahadei	93.3	30.0	Completed	
70	738875	3062750	Bhariya	145.1	18.5	Completed	

Notes:

(1) X and Y coordinates are taken from the 1:500,000 map of Nepal, a composite of LANDSAT imagery. On that map, the Universal Transverse Mercator grid overlay is based on the Everest Geodetic System. Latitude is measured and numbered northward and southward to the equator; and longitude is measured and renumbered every 6 degrees. For Nepal the 6 degree break in numbering occurs at approximately 84 degree East longitude. The coordinates were read with the help of project-supplied digitizer.

(2) Z is the absolute elevation of the well above the mean sea level. The elevations are interpolated from 1:50,000 scale topographic maps.

Among the project wells, the deepest is 68 m deep (UN 12, Panani), and the shallowest only 34 m (UN 5, Saljhandi). Both the shallowest and deepest wells were drilled by drilling rig direct rotary method. Drilled metrage of manually drilled wells varies from 36.6 m at Siso Semara (UN 22) to 58 m at Rudrapur (UN 16). All of the project wells were constructed with 4" diameter pipe.

Out of 26 project wells, one well at Bogari (UN 24) is found to be wrongly designed. In spite of 6 m thick sand and pebble zone at 33.5 m depth, the screen is placed from 22.6 to 28.1 m,where the lithology is silt and fine sand. There is no consistency in tapping the aquifers. In 10 project wells (UN 2, 4, 5, 7, 8, 9, 10, 13, 24 and 25), aquifers relatively at deeper depths are screened despite the existence of more than 3 m thick permeable materials at shallower depths. And in the rest of project wells, upper aquifers are also tapped.

While comparing the reported lithological descriptions with electric logs, it has been noticed that the driller's logs are not corrected with the information from electric logs. However, the electric logs were considered during well design.

2.2. Testing Shallow Wells

The program had specified the pumping test of 31 shallow wells. Out of this, only fifteen wells have been tested. Among the rest, in UN 4 - Gajedi and UN 6 - Murgiya, water level fluctuations were reported during tests. In the well at Premnagar (UN 9), the static water level was at 9.47 m, so the test could not be made with centrifugal pump. And the wells UN 15, 16, 17, 18, 19, 20, 21 and 26 could not be tested due to shortage of fuel in the project (verbal communication).

In order to produce the transmissivity map of Rupandehi Terai, transmissivity values from thirteen USAID shallow wells were also taken into consideration. Locations of pump tested project wells and selected USAID shallow wells are shown in Appendix 6.

All pumping test interpretations of project wells are appended to this report in the group of Appendices 5. The interpretation is based on the proprietary UN/DTCD computer program which includes a measure of appropriate formula fit (standard deviation).

In 10 wells, the duration of pumping was 3 hours. In one 2 hours, in two less than 10 minutes (because of dryness of wells) and in the remaining two, though the duration is 180 minutes, usable is only first 16 to 30 minutes due to fluctuation of water levels.

It has been noticed that dynamic levels were stabilized within the pumping duration of 180 minutes, so the test duration of 3 hours seems to be sufficient.

In order to know the storage coefficient of the aquifers in Rupandehi Terai, most of the project well tests had included observation in the nearby existing shallow drilled wells also. But the result came out to be ridiculous, big differences in transmissivities found between pumping and observation wells. The results are as follows:

Well No.	Pumping Well	Observation Well
UN 1	3691	11814
UN 2	6953	18033
UN 3	1292	300
UN 7	792	18962
UN 8	555	29823
UN 10	2585	31552
UN 11	655	26307
UN 13	43	1673
UN 14	1817	6200
UN 22	208	72
UN 23	592	1031
UN 24	141	923
UN 25	142	2964

Hence, the storage coefficient values obtained from observation wells are not considered. The outcome is suspected to be due to screening different aquifers in project wells and nearby already existing shallow wells. It could have been proved if the well construction data of those wells were known.

2.3. Monitoring Water Levels

In Technical Report No. 2, three maps from Rupandehi district were presented showing maximum and minimum depths to water table in 1987 and the rise of water levels between the minimum and maximum of 1987. Likewise in Technical Report No. 13, five maps showing the rise of water levels between minimum and maximum of 1987 and 1988, depths to water table in June and September 1988 and in May 1989, are included. And present report is updated with four more maps: depth to water table in September 1989, rise of water levels between May and September 1989 and water level contours in May and September 1989.

In May 1987, water levels were started to be monitored in dug wells and hand pumps. The network of observation wells is shown in Appendix 2. The idea to build a permanent monitoring network is to replace the original network of dug wells and hand pumps with project drilled wells of which lithology is known, transmissivity eventually calculated and land surface elevation surveyed. This "new" monitoring network will include only project wells and observations in dug wells and hand pumps will be stopped probably from January 1990.

Depth to water levels was observed in bimonthly intervals from May to November 1987, then onwards it was changed to once-a- month. In the month of September 1989, the network included 17 dug wells and 4 hand pumps. It is regrettable that project wells, which were completed in July, and some as early as February 1989, are still not yet included into the network.

The evolution of water table in shallow aquifers of the Rupandehi Terai is illustrated with several appendices in this report (Appendix 7: correlation between depth to water table in selected wells and rainfall; Appendices 8: depths to water table in June and September 1988, May and September 1989, the rise of water table between May and September 1987, June and September 1988, and May and September 1989; Appendices 9: individual hydrographs of 14 monitored wells which have regular water level information).

3. SHALLOW AQUIFER LITHOLOGY AND AQUIFER PARAMETERS

3.1. Lithology

Project wells have penetrated through upper 50 or so meters of an alluvial sequence, which is commonly known as the Terai Plain. The Plain is composed of interlocked alluvial deposits of the wider Ganges Plain and that of fans, channels, flood plains of numerous rivers flowing from the Siwalik Range and across the Terai Plain, as well as colluvial deposits at the foothills of the above range. The most prominent lithological-morphological unit is the Bhabar Zone.

The Bhabar Zone is a stretch of torrential deposits nearby Siwalik hills, being composed of outwash, boulders, cobbles, gravel and sand, and characterized by extremely poor sorting. Because it was formed as a result of river fan and colluvial deposition, the Bhabar Zone is not continuous. Between fans the Bhabar is often not present.

Very high permeabilities of the Bhabar sediments have been reported (50 to 200 meters per day) in other districts. Tillson in his 1985 report speculates about the area occupied by the Bhabar sediments in Rupandehi district. His estimate is 100 km^2. Hydrogeologists from Bhairawa-Lumbini irrigation project estimate the Bhabar to be twice that much.

The bulk of the Terai sedimentary basin belongs to Holocene alluvium which includes present day alluvial deposits, channel sand-and-gravel deposits, outwash deposits. Due to their fluviatile origin and constant shifting of stream channels, these deposits are crossbedded, eroded, reworked, and redeposited.

The lithology of the shallow ground water system in Rupandehi district is known from some 26 "project" wells, 23 USAID wells, 10 BLGWP wells and 11 Japanese Red Cross wells. (There are also over 100 deep tube wells drilled for the Bhairawa-Lumbini project, which contain lithological information on upper layers as well.)

Lithological cross sections of Rupandehi Terai are presented in group of Appendices 4. There was no attempt to connect permeable layers in lithological cross sections. This is a "risky" undertaking in Quaternary deposits near to the foothills of sediment-supplying mountains and in an area cross-cut by many present rivers and buried channels. It is believed that the lithology of the upper 30 or so meters is rapidly changing over very small distances. Present-day and past-time rivers have been changing their streambeds; they have been either depositing or eroding sediments, leaving behind either coarse sediments or impermeable fine deposits.

Out of the total drilled metrage in 26 "project" wells of 1226 m, 372 m are sand and gravel deposits. This means that about 30% in an average shallow well is composed of sand and/or gravel. (An "average" well in this drilling program is 47 m deep, out of which 14 m are composed of permeable, and 33 m of impermeable deposits.) The percentage of permeable materials in Rupandehi district (30%) is little less than in Kapilvastu district (32%) and is much less when compared to Nawalparasi-West (48%), Sunsari (56%), Rautahat district (39%), Morang (38%), Dang (48%) and Deukhuri (53%). However, when the upper 47 meters of all wells drilled in the district are taken into account, the average percentage of permeable materials comes to about 38%. Of interest is to note the decrease of this percentage with depth. The following table shows the trend (the data base contains 69 wells, which are more or less uniformly spread all over the district).

Depth Interval	Total Drilled	Total Permeable	Percentage Permeable
10	690.0	290.5	42.1
30	2016.5	713.6	35.4
47	2934.6	1002.4	34.2
60	3381.2	1140.7	33.7
100	4206.3	1409.6	33.5
150	4899.0	1585.0	32.4
200	5134.5	1618.0	31.5
300	5230.1	1630.1	31.2

Clearly, the near-the-surface ten-meter layers are most permeable. One may say that the upper ten meters are composed of 4.2 m of permeable and 5.8 m of impermeable materials. The percentage of permeable materials gradually, but very slowly, drops with depth. The following may be concluded from the above analysis:

(1) The rain can easily enter the subsurface because there is a large proportion of permeable materials underlying the surface.

(2) More permeable materials are to be expected in shallow depth than in deeper parts. Although the trend is evident, it is not so alarming. (The "permeability" in this context is qualitative rather than quantitative category. One meter of gravel with coarse sand at depth in deep Rupandehi aquifer may mean more transmissivity than 5 meters of fine to medium sand in shallow aquifer.)

(3) Evidently an extensive and thick clay layer, which presumably separates deep from shallow aquifer, does not exist in Rupandehi. If it did exist, there would be a sharp decline of permeable percentage at certain depth, say between 60 and 100 m. On the contrary, each interval in Rupandehi contributes about three meters of permeable material in every ten meters drilled.

For lithological interpretation of Rupandehi, additional 44 well logs are included herein and their percentage of permeable materials are also calculated and presented here below.

Type & No. of Wells	Average Depth	% of Permeable Materials
UN STW - 26	47 m	30%
USAID Well - 23	47 m	34%
BLGWP DTW - 10	47 m	38%
Japanese STW - 11	27 m	46%

(The overall percentage is 38%.)

Note:- USAID & BLGWP wells are deeper in depths, since the average depth of UN STW is 47 m, this depth is considered for calculating above given figures.

Project shallow wells and selected USAID wells and BLGWP wells are quite scattered in the district. Though Japanese Red Cross shallow wells are also scattered, they are relatively shallow drilled. Depths of the wells included in this report vary from 10 to 35 m (average depth - 27 m).

If all scattered wells with 47 m available depth are considered for calculation, then the percentage of permeable materials in Rupandehi Terai becomes 33%.

A map showing equal thickness of permeable materials within 47 m depth is presented in Appendix 3A taking into consideration all project wells, USAID wells and BLGWP wells. In the north-eastern part of the district, the thickness of shallow aquifer is more than 20 m and in the rest of the areas it goes even down to 3 m. However, one can easily visualize that most of the areas in Rupandehi have about 15 m of permeable materials within 50 m depth.

One of common earlier interpretations is that going from north to south the lithology of shallow aquifer becomes finer. When lithological cross-sections are consulted (Appendices 4), following interpretations came out.

The northern zone belongs to Bhabar formation, and streams cutting the Siwalik hills must have contributed permeable materials. The Bhabar formation normally contains the greatest proportion of coarse-grained material but it is poorly sorted and generally overlain by silty and to some extent clayey deposits. In addition to this, the Bhabar zone is not continuous everywhere east west. This can be visualized in lithological cross section I - I' and has been already explained above at the beginning of this chapter.

The grain size of aquifer materials becomes finer not only from north to south but also in any direction. It is obvious in the lithological cross sections I - I' to IX - IX'. Two examples are illustrated below.

In the east-west lithological cross section I - I', grain size becomes finer at well JR B/81 while going from east to west, again becomes coarser at well UN 6, finer at wells JR A/76 and JR B/75 and again becomes coarser at well UN 5. From well US 5/18 which is in the central part, the grain size becomes finer towards the eastern end of the district.

In the north-south cross section VIII - VIII', wells UN 22 and 25 which are located in the south have coarser materials compared to the well UN 23 in the north.

It is noticed that overall the middle part of Rupandehi along Tinau river and to some extent to the east of Bhairahawa-Butwal highway seems to be rather coarse. This belt runs throughout the district in northeast-south-west direction.

With the above comments in mind, and with all reservations with respect to quality and quantity of information, one may conclude that in Rupandehi district in most places there is a chance of getting at least 10 meters of sand and/or gravel within a depth of 50 m from ground level and that a shallow well to supply drinking water to villages can be constructed without too much uncertainty. It is difficult to say whether large-capacity irrigation wells can be forecast with equal certainty without a more detailed exploration program. The chances of finding excellent aquifers at shallow depths are tied to locating buried channels in which coarse sediments have been deposited.

3.2. Hydrogeological Parameters

Hydrogeological parameters of shallow aquifers were obtained from 15 pumping tests run on "project" wells and 13 USAID shallow wells. The wells used in this interpretation are shown in Appendix 6, which is the map of transmissivity. In the same time, this report contains a group of appendices (Appendix 5) with 15 project well pumping tests. Each test is interpreted in the same way, using a rather objective computer match between field data and theory. A comparison was made between the classical non-leaky theory of Theis and Jacob with the leaky-aquifer theory of Hantush. The result with lower standard deviation, or a better fit, was accepted. In all tests, the classical Jacob interpretation produced quite a good fit. The transmissivity of shallow aquifer is shown in Appendix 6 (the transmissivity map). The map is the creation of a computer contouring program, which interpolates and extrapolates random individual values. This inter-extrapolation process is based on only 28 values which is not sufficient to accurately describe the whole Terai part of the district. There are also some reservations as to the quality and accuracy of reported pumping tests, considering poor development, fluctuations in pumping rates, and inaccurate water level measurements. Likewise, since not all wells were drilled to the same or similar depth, the

distribution of transmissivity cannot be taken as absolutely correct. The interpretation shall be attempted with information in hands.

Among the project wells, UN-2 Manoharpur located in the north central part of Rupandehi has shown the highest transmissivity value of 6953 m^2/day , whereas the lowest transmissivity of 43 m^2/day (not only among the project wells but also among all shallow wells so far pump tested) is found in UN-13 Parasi Jhunga, which is in the southeastern part. Generally the transmissivity of shallow aquifers is increasing inwards from the periphery. As expected , the higher transmissivity areas are located along the course of Tinau river and to some extent to the east of Bhairahawa-Butwal highway. Higher transmissivity belt extends upto Butwal in the north, which is right at the Bhabar zone. However, among the twenty eight shallow wells considered for the map of transmissivity, the highest is found in USAID well US 5/14 at Manigram (16465 m^2/day), which is located in the central part of the district about 7 km south of Butwal. One can easily see that the transmissivity is higher in the Bhabar area. And one noticeable thing is that between eastern and western piedmonts, western looks better in the transmissivity map.

There is a clear distinction in transmissivity distribution. Higher transmissivity zone exists in the central -north and continues to the central-south and northwest parts having more than 2000 m^2/day. Patches of lower transmissivity areas are located in the central- west, south west, northeast and northwest possessing only several hundred square meters per day.

Well No.	Transmissivity (m^2/day)	Aquifer Thickness (m)	Hyd. Conductivity (m/day)	Aquifer Type
UN 1	3691	6	615	G
UN 2	6953	16	435	G
UN 3	1292	6	215	G
UN 5	2956	8	370	G
UN 7	786	5	157	G
UN 8	551	8	69	G
UN 10	2585	13	199	G
UN 11	655	8	82	G
UN 12	284	5	57	G
UN 13	43	9	5	S & G
UN 14	1817	7	260	G
UN 22	208	3	69	S
UN 23	592	5	118	S
UN 24	141	6	24	S
UN 25	142	13	11	G

Note:- G = Gravel, S = Sand

It can be seen in the table that out of 15 project wells, only in one well the conductivity has not matched with corresponding lithology (Well No. UN 25 at Bichawapur). Hydraulic conductivity of 11 m/day is the lower range of sand and gravel aquifer characteristics. Gravel should have conductivity at least 40 m/day. One can easily conclude that either the reported lithology is not correct or the well is not properly constructed and/or developed.

4. FLUCTUATIONS OF SHALLOW WATER TABLE

4.1. Monitoring Network

Rupandehi district is well covered with observation network. Actually the observation of shallow water table started (GDC) in May 1987 with 39 dug wells and 1 hand pump in the network. But from July 1987 onwards new network,including only two dug wells from May1987, is built and continuing till now. In the future, from January 1990 onwards, the observation will be done only in project wells.

4.2. Rainfall in Rupandehi in 1987, 1988 and 1989

To understand better the rise of shallow water levels from the driest month through the wettest month (1987/1988/1989) one should look at rainfall in the June-September period. As shown in Figure 1, the two rain gauging stations within the Terai portion of Rupandehi district: Bhairahawa Airport in the central south and Butwal in the central north are taken into consideration for the purpose of this report. Monthly rainfall data of Bhairahawa Airport are available from January 1987 to August 1989 but Butwal has data only for 1987. However, for comparison between northern and southern parts of the district, 10-year annual rainfall data of both stations are presented below.

	Annual Rainfall (mm)	
Year	Bhairahawa Airport	Butwal
1987	1408	2632
1986	1849	2374
1985	1540	2321
1984	2240	2942
1983	1514	2221
1982	1673	-
1981	2468	2009
1980	1725	1851
1979	1396	2012
1978	1544	1556
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Average	1736	2213

The difference in annual rainfall between Bhairahawa Airport and Butwal is 474 mm in average.

The comparison between monthly rainfall in 1987, 1988 and up to August of 1989 recorded at Bhairahawa Airport is shown in Figure 4. Annual rainfall in 1988 was 708 mm higher than in 1987. And also the 1989 rainfall has already been more than 1987 while considering only the rain through August. Comparison of monthly rainfall of 1987 recorded at Bhairahawa Airport and Butwal is presented in Figure 5.

The monthly rainfall recorded at Bhairahawa Airport is plotted alongside water table fluctuations in Appendix 7 to indicate the relationship between the rainfall and water table rise and decline in the period from May 1987 to September 1989 for 2 dug wells and 2 hand pumps selected from different parts of the district as representative.

Among those four, Saljhundi Hand Pump located at northwest part of the district has shown minimum depth to water table gradually increasing from 1987 to 1989 and maximum depth to water table in 1989 more than that in 1988. Whereas, other handpump existing in the northeast of the district has shown minimum depth to water table gradually decreasing from 1987 to 1989 and maximum depth to water table in 1988 less than that in 1989. Two dug wells selected from central and southern parts of the district show similar water level fluctuation behavior regardless of difference in the amount of rainfall in 1987, 1988 and 1989.

4.3. Shallow Ground Water System Hydrodynamics

Hydrodynamics of the shallow ground water system in Rupandehi district in 1987, 1988 and 1989 is presented in Appendices 8/1 through 8/9 and 9/1 through 9/5. The group of Appendices 8 refers to the depth to water table in relative terms (pre-and post- monsoon in 1988 and 1989 and rise of levels during this period in 1987, 1988 and 1989) and water level contour maps of pre- and post-monsoon 1989. Similar maps have already been presented in Technical Report No.2 for the year 1987 and in Technical Report No. 13. In this report the maps are updated to pre-monsoon 1989.

The maps of maximum depths to water table in June 1988 and May 1989 (Appendices 8/2 and 8/5) show similar behavior of the shallow ground water system in the period preceding monsoons of 1988 and 1989.

The maps of minimum depths to water table in September 1988 and in the same month 1989 (Appendices 8/3 and 8/6) also show similar behavior of the shallow ground water system in the post-monsoons of 1988 and 1989.

The maps of rise of water table between pre- and post-monsoon of 1987, 1988 and 1989 (Appendices 8/1, 8/4 and 8/7) do not show big differences in the fluctuating behavior of shallow ground water system of Rupandehi.

Except in one well, Shankarnagar, located in the north-northeast of the district, the rest of area has maximum depth to water table varying from 2 to 6 m. At Shankarnagar the maximum depth to water table was above 10 m. The range of variation in minimum depth to water table is from 0.2 to 3.2 m. Regarding the rise of water table between pre- and post-monsoon, except at Shankarnagar (rise about 8 m), the rest of area shows the rise between 0.2 and 4.4 m.

Appendices 8/8 and 8/9 present water level contour maps in May and September 1989, respectively. As expected the general direction of ground water flow is from northeast to southwest. There is not so much difference in gradients of ground water flow in either of these two maps. The gradient of flow in the northern part is mostly about 0.003, or 3 meters per one kilometer. There is a change of gradient from contour line 120 (Karhaiya). The gradient becomes gradually more gentle, first about 0.0016 in the central part of the district, and finally 0.0006 at the southern end.

The change of gradient may be an indication of the change of transmissivity, which should then be higher in southern compared to northern part. Yet, in the case of Rupandehi district, the change of gradient is an indication of less water flowing through cross-section in the southern part. The southern part is an area of very high evapotranspiration potential. Plenty of water coming from the north is released through evaporation process, so that less water flows through about the same transmissivity.

The map of contours in September 1989 is similar to the map in May, which means that the flow pattern is the same. In the northern part the difference in contours is about 5 m whereas in the south it is about 2.5 m.

The group of Appendices 9 present individual hydrographs of 10 dug wells and 4 hand pumps, of which regular well observation data from at least January 1988 to September 1989 are available.

Analysis of those hydrographs showed the following:

Minimum depth to water table is rising from 1987 to 1989 in Saljhundi, Ramnagar, Rayapur, Manpakadi, Karmahawa and Farsatikar, whereas declining in Devdaha, Sitapur and Sisawa. Likewise, the maximum depth to water table is increasing in Saljhundi, Devdaha, Manpakadi and Karmahawa, whereas decreasing in Sitapur, Rayapur, Sisawa, Tamnagar, Shankarnagar, Farsatikar and Bhairahawa. Dug wells at Belhiya, Chhoti Ramnagar and hand pump at Ramnagar showed no difference in the maximum depth to water table. Similar behavior of minimum depth to water table is noticed in Belhiya, Shankarnagar and Bhairahawa dug wells.

5. ASSESSMENT OF WATER RECHARGE AND DISCHARGE

5.1. Preliminary Assessment from Basic Documentation

The following conclusions are drawn about the recharge and discharge of the ground water system in the reported area.

(1) The recharge comes from local infiltration of rainfall everywhere where more or less permeable surface permits. The percentage of infiltration may be high. But there may be plenty of rejected recharge in monsoon season because of oversaturation of the soil immediately underlying the land surface. This is mostly true in the lower part of the district, where water table in the monsoon season comes very close to the ground surface.

(2) According to Tillson (1985), the area of Bhabar zone in Rupandehi district is 100 km2. Due to coarser sediments, and presence of fan deposits, the percentage of recharge may be quite high. The percentage of direct rainfall recharge in Bhabar zone, according to Duba's (1982) estimate for all three districts within the zone is 43.7%. With rainfall about 2200 mm/year, and almost 100 km^2 of Bhabar in the district, the input into the Bhabar sediments could be about 96 MCM (million cubic meters).

(3) The outflow of shallow ground water is mostly across the border into neighboring India. The outflow into India across the border is calculated approximately with gradients from Appendices 8/8 and 8/9 and transmissivities from Appendix 6. The length of outflow section is 40 km. The transmissivity increases from 160 m^2/day at Vishnupura to 1000 m^2/day in the middle of the section and again decreases to 200 m^2/day towards west. The gradient in the eastern half is about 0.0016 and in the western half about 0.0008 of the outflow section. The volume of water that may be outflowing is about 21,400 m^3/day or 7.8 MCM/year (million cubic meters in one year). This happens to be a small fraction of the potential annual recharge from infiltrated rainfall. If, conservatively, only 10% of annual rainfall of 1900 mm infiltrate and recharge the shallow aquifer, the volume of recharge over an area of about 1140 km^2 could be about 216 MCM/year. The difference between this hypothetic recharge of 216 MCM and outflow into India of about 7.8 MCM is discharged through evaporation process (dominantly), into the Tinau, Dano and other rivers and withdrawals from dug and drilled shallow wells (minor component at present). Yet, one may not discard an eventual relationship between shallow and deep aquifers in Rupandehi. The maps of heads in both aquifers indicate that shallow aquifer head is above deep aquifer head in most of district, and certainly in the northern part, above the BLGW project area. Downward leakage from shallow aquifer into the deep aquifer is both possible and probable. Likewise, the whole recharge in Bhabar zone, where both shallow and deep aquifers outcrop, is divided between the two.

(4) A rough estimate of the possibility of recharge is made by assuming the effective porosity of sand and gravel aquifers as 15% and considering that the average rise of water table during monsoon period is 2.3 m over an area of 1140 km2. If one third of these 2.3 meters is composed of permeable deposits (the average percentage of permeable formation from total shallow depth was about 33, see Section 3.1), the net result is about 130 MCM. In this estimate, the rejected recharge due to saturation of soil during rainy period and the evaporation loss due to high water table during hot period are not included. In fact, there will be more recharge than above mentioned, if the water level is lowered by pumping. This 130 MCM is a conservative estimate, or a minimum under present, or natural, conditions.

(5) It may also be considered that the land surface is not permeable in the whole area. When thick clay deposits underlie the surface, there is no direct recharge by infiltrated rainfall. There are varieties of soils existing in the area and provided with various irrigation system. Average rainfall in the area is about 1900 mm/year. Tillson (1985) has mentioned the percolation rates of three varieties of soils ranging from 156 to 504 mm/year. By taking the average percolation rate of 330 mm/year (about 17% of rainfall) in the area of 1140 km^2, the total recharge to shallow aquifer in Rupandehi can be estimated as about 375 MCM. The outflow into India is a very small fraction of that volume, so that most of ground water must be lost through evaporation process. This is the water that can be salvaged by carefully planned exploitation, provided that the lithology of shallow aquifer (that is its thickness and transmissivity) permit the ground water development by pumping.

(6) In addition to the loss by evaporation, there is a downward leakage of infiltrated water from layers with higher piezometric head to layers with lower head. The lithology of aquifers, as shown in lithological logs and cross sections, has excluded the presence of a continuous clay layer, that may, if present, effectively cut off one aquifer from the other. Permeable layers are present at every depth, at a ratio of one meter of sand and gravel to two meters of clay. This leakage from shallow into deep aquifer, especially in the BLGW project area, in which there is a decline of piezometric heads of deep aquifer, cannot be quantified without a mathematical model.

5.2. Assessment of Water Balance by Mathematical Modelling

The volume of data appears to be sufficient to construct a preliminary model of Rupandehi district. However, there appears to be little point in making a two-dimensional model dealing only with shallow aquifer, if the major issue is the connection between the two, now and in future, under very large deep aquifer pumping. The zone of recharge is common to both, and vertical hydraulic connection between the two is a reality rather than hypothesis. One should create a two-layered model, with the possibility of leakage through a semiconfining layer depending on the sign of the head difference. Available information from both aquifers is such that at least a preliminary two-layered model can be made.

In order to make the model as reliable as possible under the present situation, one needs to do the following:

(a) To compile all information on water levels, accurately expressed in absolute elevations within the same frame of leveling. Water level record dates back to late 1960's, when USAID drilling campaign produced first water levels in deep and shallow wells. Evolution of levels (heads) in deep aquifer prior to 1983/84 when pumping from deep wells in BLGWP started, should be carefully analyzed. Likewise, maps of current heads in both aquifers should be prepared showing differences of heads in May and September of 1983/84 and now.

(b) Additional pumping tests might be needed, with correctly interpreted transmissivity values in existing shallow tube wells.

(c) To redevelop some of dubious wells, and to repeat the testing.

(d) To make an inventory of currently used shallow tube and dug wells with some control over withdrawals.

(e) To monitor water levels on a bi-weekly basis in the next year monsoon period.

(f) To extend the study to distant areas in western, southern and eastern direction, especially in the southeastern corner which belongs to India. The propagation of piezometric head changes travels very fast and very far. With storage coefficient of deep aquifer of about 0.0001 and transmissivity 5,000 m2/day, the distance to which the head change may travel in 100 days is about 100 km.

The model may provide quantitative answers to the following:

(a) Recharge from rainfall in the Bhabar Zone and elsewhere.

(b) The importance and magnitude of the evapotranspiration process in shallow aquifer.

(c) The correct order of magnitude of hydrogeological parameters (permeability and transmissivity) in either aquifer.

(d) The volume of outflow across the district boundary into India.

(e) The past and present impact of deep aquifer development in BLGWP area, Stage I, on heads in shallow aquifer.

What is most important the model, if properly structured and calibrated, can predict the effect of additional pumping in Stage II and Stage III wells on deep and shallow aquifer, in Rupandehi and neighboring India.

The modelling of Rupandehi ground water system is a serious task, with plenty of benefits. It is estimated that at least two months of continuous work are needed to make the multi-layered model, provided all information is compiled, interpreted and in hand.

The aquifer system to be modeled (Appendix 10) has only one natural and three artificial boundaries. The natural boundary is the impermeable boundary in the north, being the physical termination of the shallow (and deep) ground water system of the Terai. The artificial boundaries of the district in the sense of the regional ground water system are the boundaries to the south (Nepal-India border) and east and west (district boundaries with Nawalparasi and Kapilvastu districts).

The final outcome of the model could be the amount that can be annually developed by shallow and deep wells. In the case of the shallow aquifer, the consideration shall be given to recharge, salvaged water on account of ground water evaporation, vertical leakage downward to deep aquifer. In the case of deep aquifer, the primary components shall be the recharge in outcrop area, abstraction in project areas, natural down-the-gradient flow toward south, and recharge in the form of induced leakage. This last factor is expected to become more and more important with progressive development of cones of depressions in deep-aquifer pumped areas.

The basis for model calibration, i.e. for the verification of all system parameters, should be the evolution of heads in shallow and deep aquifer since 1983. If only shallow aquifer is considered, it could be calibrated with matching water levels from pre- to post-monsoon of 1989 correlated with rainfall, decline of water levels from post monsoon 1989 through pre monsoon 1990. All three maps of water flow, should be matched by the model. Unfortunately, project-drilled shallow wells missed the monsoon season of 1989, and maps presented in this report are based on dug wells and hand pumps.

Only at the end of the modelling study the water balance of the shallow ground water system and its development potential can be formulated. Without a comprehensive evaluation of the whole system, including all its components (recharge-flow-discharge), any quantification of the shallow ground water system behavior and development potential is only a speculation.

Main components of a two-layered model of the Rupandehi ground water system are the following.

(a) Size. Almost the whole Terai portion of the Rupandehi district shall be modeled, with the India-Nepal state border as the south boundary, the contour line 150 m on its north, and the district boundaries with Nawalparasi on its east and Kapilvastu on the west. The area involved in the model shall be about 42 km (north-south) by 38 km (west-east) (Appendix 10). This model will include some part of Indian territory also in order to cover whole Rupandehi. The model corners shall have coordinates in X direction from 720000 to 758000, and in Y direction

from 3026000 to 3068000. The discretization shall be 1000 m in each direction, creating a uniform mesh network of 1 km^2 each cell. Thus the model shall have 1596 cells.

(b) The model shall be **multi-layered**, or "quasi" three- dimensional. The geometry of the shallow ground water system shall demand the following data input for each cell: (i) land surface elevation, (ii) top of aquifer elevation, (iii) bottom of aquifer elevation, (iv) initial water level elevation. Other input matrices (one value for each cell) shall be the following: hydraulic conductivity of the shallow aquifer, storage coefficient of the shallow aquifer, recharge from rainfall infiltration, discharge through evapotranspiration process. Deep aquifer shall be defined by transmissivities and storage coefficients. Likewise, both space and time distribution of pumping in BLGWP area must be known. The connection between the two aquifers shall be via leakance, that is the ratio of hydraulic conductivity of semipermeable layer to its thickness. Pumping tests of both shallow and deep wells need to be re-evaluated, paying attention to confirming a better fit of data with Hantush leaky theory which might produce leakance values.

(c) The period of calibration shall depend on availability of shallow water levels. If nothing else, then the current period can be used for calibration (1989-90). The forecast-of-future scenarios should be discussed with BLGWP management, and World Bank evaluation team.

6. CONCLUSIONS AND RECOMMENDATIONS

The objective of this report is to present technical information on the occurrence of shallow ground water in Rupandehi district. It is presented in a form of a basic documentation with some preliminary interpretation.

The drilling program which was formulated about a year ago, was not completed according to expectations. Twenty six holes were drilled with the total drilling metrage of 1226 m. The average depth of newly completed wells is 47 m. Considering the lithology of shallow ground water system, this depth is probably adequate for the project purpose. Out of 26 drilled wells, 17 wells were constructed by drilling rig, and nine wells manually.

It may be too early to conclude on advantages and disadvantages of a particular method of shallow wells constructions in the Terai. Manually-drilled wells have a better control over lithology of penetrated strata; likewise, they are cleaner and pumping tests are more reliable because aquifers and well screens are less clogged than in bentonite-drilled wells. However, these advantages fade when the total depth of penetration is taken into account.

The average percentage of permeable materials (sand and/or gravel) within 47 m depth is about 38% in Rupandehi district. Analysis of lithological logs suggests that the north-eastern part of the district has more than 20 m permeable materials within the shallow depth. In most part of Rupandehi district the average permeable thickness, wihtin the upper 50 m, is about 15 m.

As a conclusion of the drilling program in Rupandehi district the following may be inferred.

Driller's logs should be corrected with the information from electric logging made in boreholes. Upper first permeable zone (between 10 to 20 m) should be screened if at least 3 m thick sand and/or gravel formation is encountered. More attention should be given to well development. Better supervision of drilling, well design and development activities is needed to produce better wells.

In addition to lithology of shallow aquifers, which becomes known from drilling operation, pumping tests provide most of knowledge on aquifer parameters. After completing a tube well, its development and test should follow subsequently. There is no reason to postpone the testing. In Rupandehi the pumping test program partially failed. Twenty six wells have been constructed and only 15 were pump tested. Among these fifteen, four were of less than 30 minutes duration. Same as in other districts, much more attention should be given to the aquifer test part.

Moreover, the fact is that in eight project-drilled wells pumping test have not been attempted. The explanation given verbally was that shortage of fuel prevented the testing. In fact, fuel shortage started when UN-14 well was drilled. The sequence of wells that followed, through UN-19, was all done manually. Then again, fuel became available. In spite of available fuel, instead of testing well UN-15 to UN-19, the remaining wells (UN-20, 21 and 25) were constructed with rig machine. Clearly, from locations of project wells, one may notice that preference was given to number of tube wells rather than to information important for quantifying shallow ground water system. Some wells are located very near to each other. Better and more representative coverage of the district would be more beneficial. In critical fuel shortage period, rig machine was used in southern part of the district where one shallow well has already been constructed under the same programme and in which the testing of recently constructed wells has been neglected (Siso Semara and Bichawapur).

The test pumping program in Rupandehi district should be continued. There are many wells which lend themselves to testing. If remaining wells are tested after proper development, the wealth of information and knowledge about the district would be enormously improved. Likewise, the project wells which were poorly developed could be redeveloped properly and re-tested. Otherwise, there is always a possibility to be mislead when attempting to make assessment of ground water system balance, whether analytically or by means of mathematical models.

Rupandehi district is well covered with water-level monitoring network. In the month of September 1989, the network has included 17 dug wells and 4 hand pumps. The proposed network for future monitoring shall include only 26 "project" drilled shallow wells. Observations in these wells have started since August 1989. Observations of water levels in dug wells and hand pumps will be stopped from January 1990.

In most of the area the levels in driest months (May-June) are within 5.0 m below the land surface. Only at Shankarnagar water is more than 10 m deep. Between pre and post monsoon period (May-June to September) the levels rose in most of the area between 0.2 and 4.4 m, whereas at Shankarnagar, the rise of level was more than 8 m. The water levels started rising in the month of June as a direct response to June rainfall. The near-maximum water levels were established in the month of September. The high September levels are the response to rainfall of about 1200 mm in July and August.

The depths to water table in September indicate that levels are very close to the land surface: almost everywhere within 3 m. Among 21 monitored shallow wells, Rayapur, Saljhundi, Karhaiya, Manpakadi and Bhairahawa have water level always within 3 m. Likewise Ramnagar, Devdaha, Farsatikar and Dhakdhai have water levels only in one month below 3 m. Majhgaon, Karmahawa, Belhiya, Chhoti Ramnagar, Madhubani and Tamnagar have 3 to 6 months water levels below 3 m. And rest of the wells have more than 8 months water levels below 3 m. Except in three small patches (Shankarnagar, Semari-Sitapur and Bhagwanpur), the rest of the area seems to have potentially very high evaporation loss.

There is not so much difference in gradients of ground water flow in either of contour maps of water levels produced in this report. The direction of shallow ground water flow is from northeast to southwest. The gradient of flow in the northern part is mostly about 0.003, or 3 meters per one kilometer. There is a change of gradient from contour line 120 (Karhaiya). The gradient becomes gradually more gentle, first about 0.0016 in the central part of the district, and finally 0.0006 at the southern end.

The change of gradient may be an indication of the change of transmissivity, which, then, should be higher in southern compared to northern part. Yet, in the case of Rupandehi district, the change of gradient is an indication of less water flowing through cross-section in the southern part. As mentioned earlier, the southern part is an area of very high evapotranspiration potential. Plenty of water coming from the north is released through evaporation process, so that less water flows through about the same transmissivity.

Analysis of individual hydrographs of 14 regularly monitored wells showed that water levels in Rayapur and Farsatikar dug wells are rising from 1987 to 1989, whereas in Devdaha dug well water levels are declining. Shallow wells at Saljhundi, Sisawa, Manpakadi, Sitapur and Karmahawa have shown contrasting water level fluctuations. Saljhundi, Manpakadi and Karmahawa wells have increasing trend of minimum depth to water table from 1987 to 1989, but maximum depths to water table are decreasing. On the contrary, Sisawa and Sitapur wells have decreasing trend of minimum depth to water table and the maximum depths to water table are increasing from 1987 to 1989.

Preliminary evaluation of shallow ground water balance is presented in this report.

(1) The recharge comes from local infiltration of rainfall everywhere where more or less permeable surface permits. The percentage of infiltration may be high. But there may be plenty of rejected recharge in monsoon season because of oversaturation of soil immediately underlying the land surface. This is certainly true in the lower part where water table in the monsoon season comes very close to the ground surface.

(2) The outflow of shallow ground water is mostly across the border into neighboring India. The outflow into India across the border is estimated as about 21,400 m^3/day or 7.8 MCM/year (million cubic meters in one year). This happens to be a small fraction of potential annual recharge from infiltrated rainfall. If, conservatively, only 10% of annual rainfall of 1900 mm infiltrate and recharge the shallow aquifer, the volume of recharge over an area of about 1140 km2 could be about 216 MCM/year. The difference between this hypothetic recharge of 216 MCM and outflow into India of about 7.8 MCM is discharged through evaporation process (dominantly), into the Tinau, Dano and other rivers and withdrawals from dug and drilled wells (minor component at present). Likewise, there may be plenty of water leaking vertically downward and recharging deep aquifer, wherever the head differential sign indicates so.

(3) It may also be considered that the land surface is not permeable in the whole area. When thick clay deposits underlie the surface, there is no direct recharge by infiltrated rainfall. There are varieties of soils existing in the area and provided with various irrigation system. By taking the average percolation rate of 330 mm/year (about 17% of rainfall) in the area of 1140 km^2, the total recharge to shallow aquifer in Rupandehi can be estimated as about 375 MCM. The outflow into India is a very small fraction of that volume, so that most of ground water must be lost through evaporation process. This is the water that can be salvaged by carefully planned exploitation, provided that the lithology of shallow aquifer (that is its thickness and transmissivity) permits ground water development by pumping.

On the basis of the presented information, the feasibility of shallow ground water development in the reported area is as shown in Figure 5. Without quantifying tools, such as models, it is difficult to interpret the area in terms of suitability for large-scale development. The only way to describe the suitability for development is in relative terms. Of course, this interpretation does not go beyond the penetrated depth of, on average, 47 m.

The area in the middle and the northwest (area about 400 km^2) seem to be suitable for intensive shallow ground water development. With individual well discharge of 12 l/sec, and average pumping season of 120 days, with each well pumping for about 10 hours a day, about 1350 shallow tube wells shall be required. Each well can irrigate on average 6 hectares, provided that the agricultural demand is 8000 m3/season/ha. In this development scheme, estimated recharge is about 130 MCM, out of which only 50% is considered to be utilized. Thus a total of 8100 hectares can be irrigated, or about one fifth of the total area. This area has transmissivity in excess of 1000 m^2/day, aquifer is more than 13 m thick, and water level most of the time in the year is within 3 m depth. The spacing between wells should be about 500 m.

In the rest of the district area, individual wells can be constructed in places where water level is closer to the land surface and the transmissivity is relatively higher.

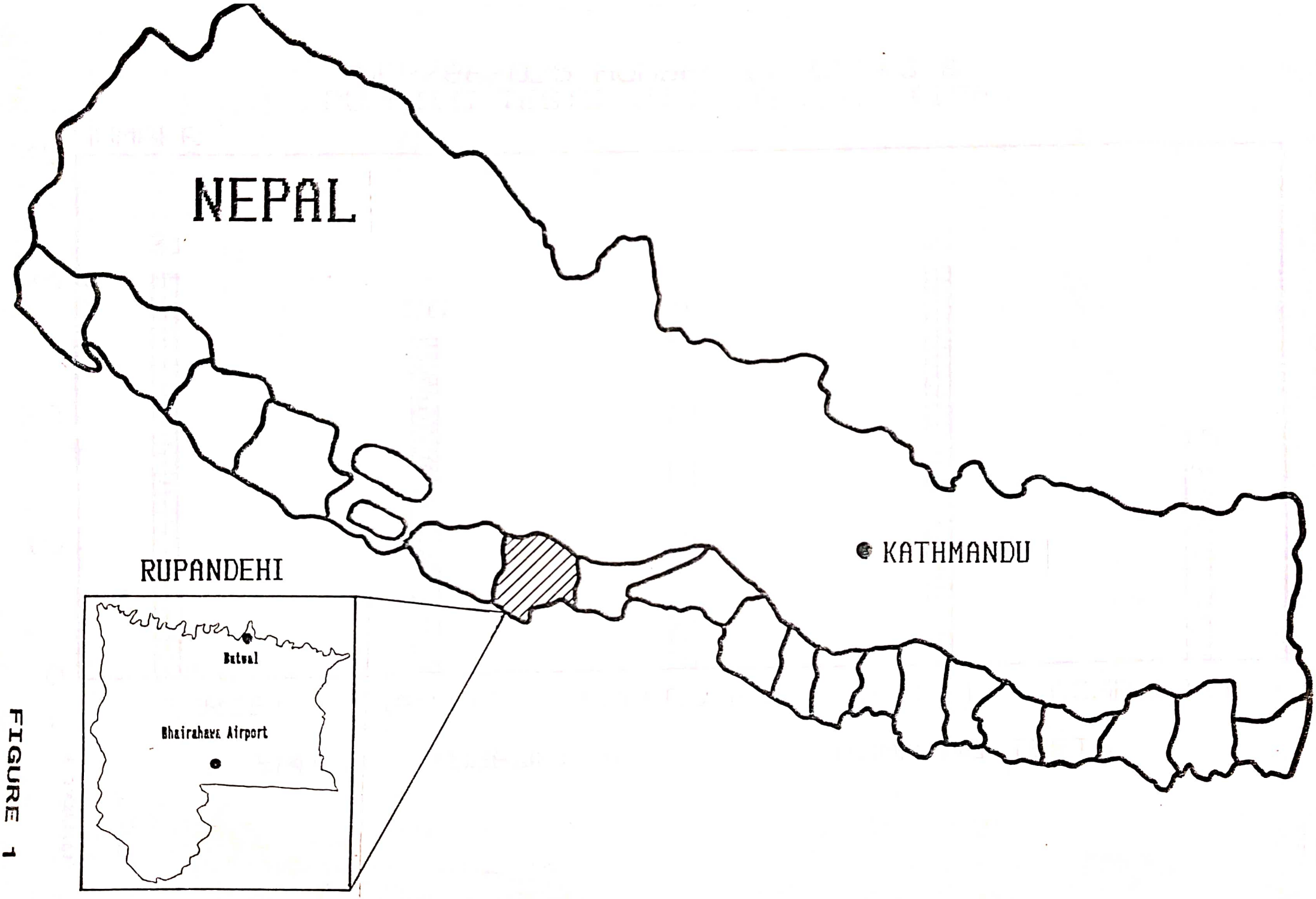


FIGURE 1

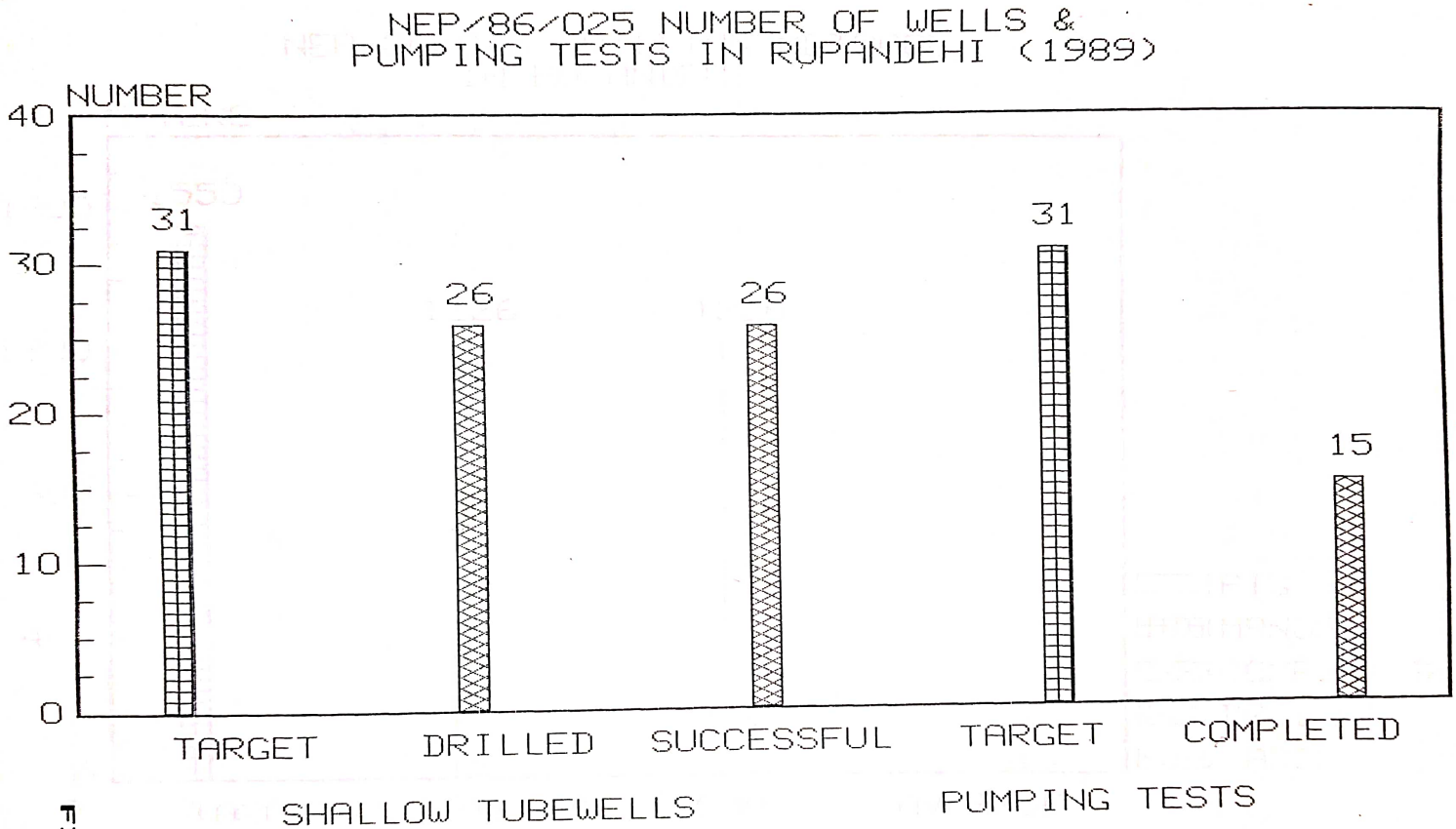

NEP/86/025 NUMBER OF WELLS &
PUMPING TESTS IN RUPANDEHI (1989)
NUMBER
40
30
20
10
0
31
26
26
31
15
TARGET
DRILLED
SUCCESSFUL
TARGET
COMPLETED
SHALLOW TUBEWELLS
PUMPING TESTS

FIGURE 2

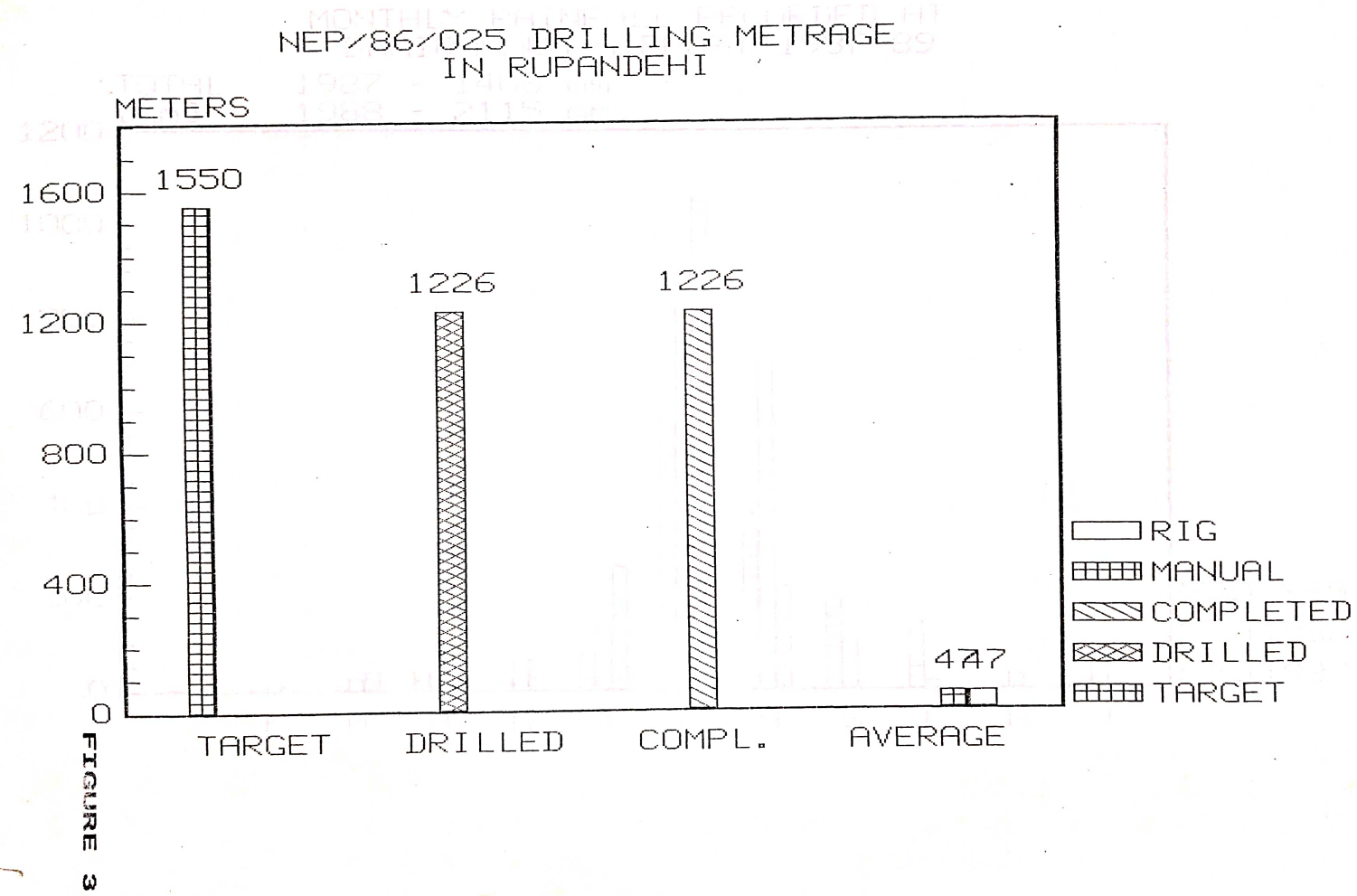

NEP/86/025 DRILLING METRAGE
IN RUPANDEHI
METERS
1600
1200
800
400
0
1550
1226
1226
447
TARGET
DRILLED
COMPL.
AVERAGE
RIG
MANUAL
COMPLETED
DRILLED
TARGET

FIGURE 3

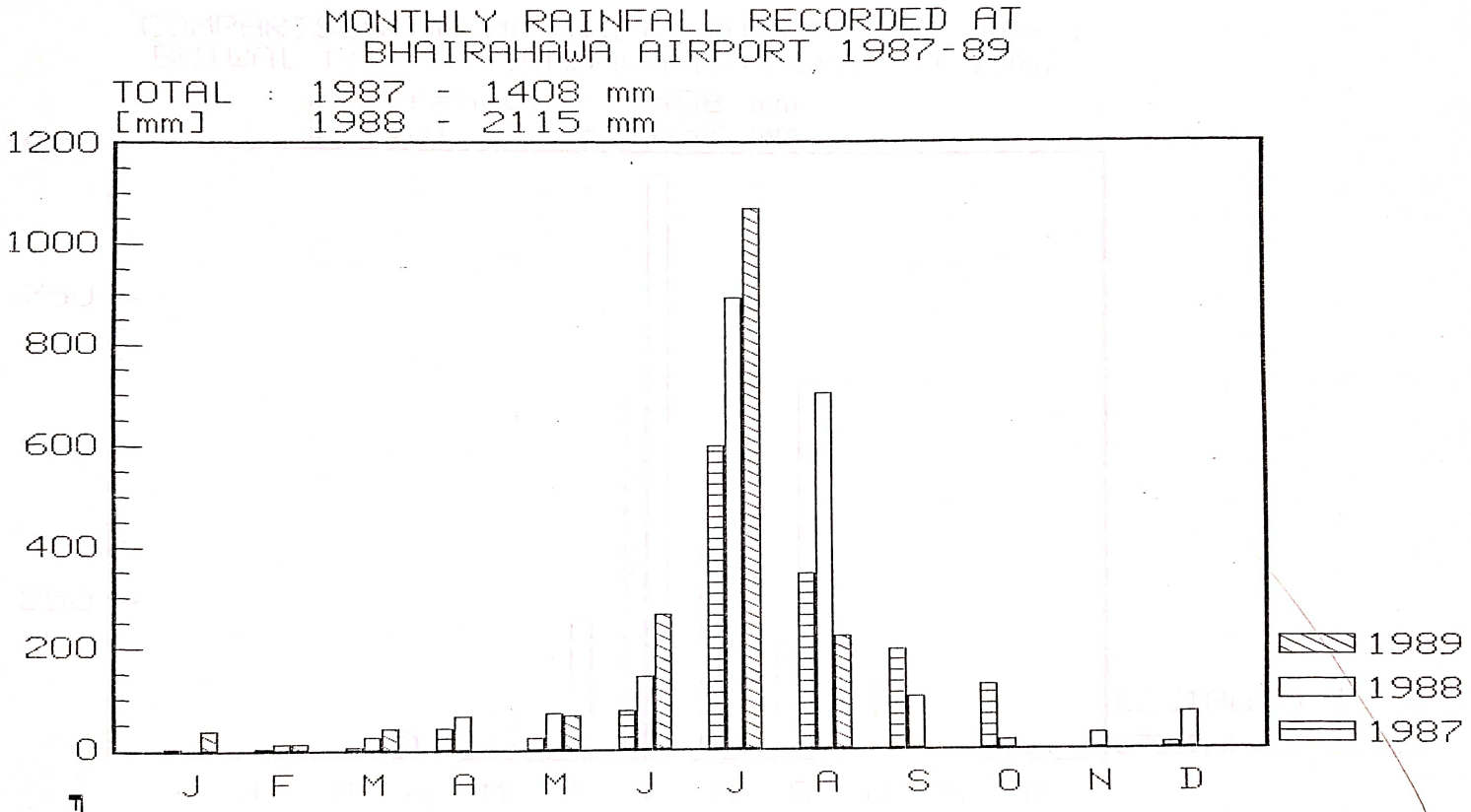

MONTHLY RAINFALL RECORDED AT
BHAIRAHAWA AIRPORT 1987-89
TOTAL : 1987 - 1408 mm
[mm] 1988 - 2115 mm
1200
1000
800
600
400
200
0
J F M A M J J A S O N D
1989
1988
1987

FIGURE 4

COMPARISON OF MONTHLY RAINFALL BETWEEN
BUTWAL AND BHAIRAHAWA AIRPORT IN 1987

TOTAL : Bhairahawa - 1408 mm
Butwal - 2632 mm

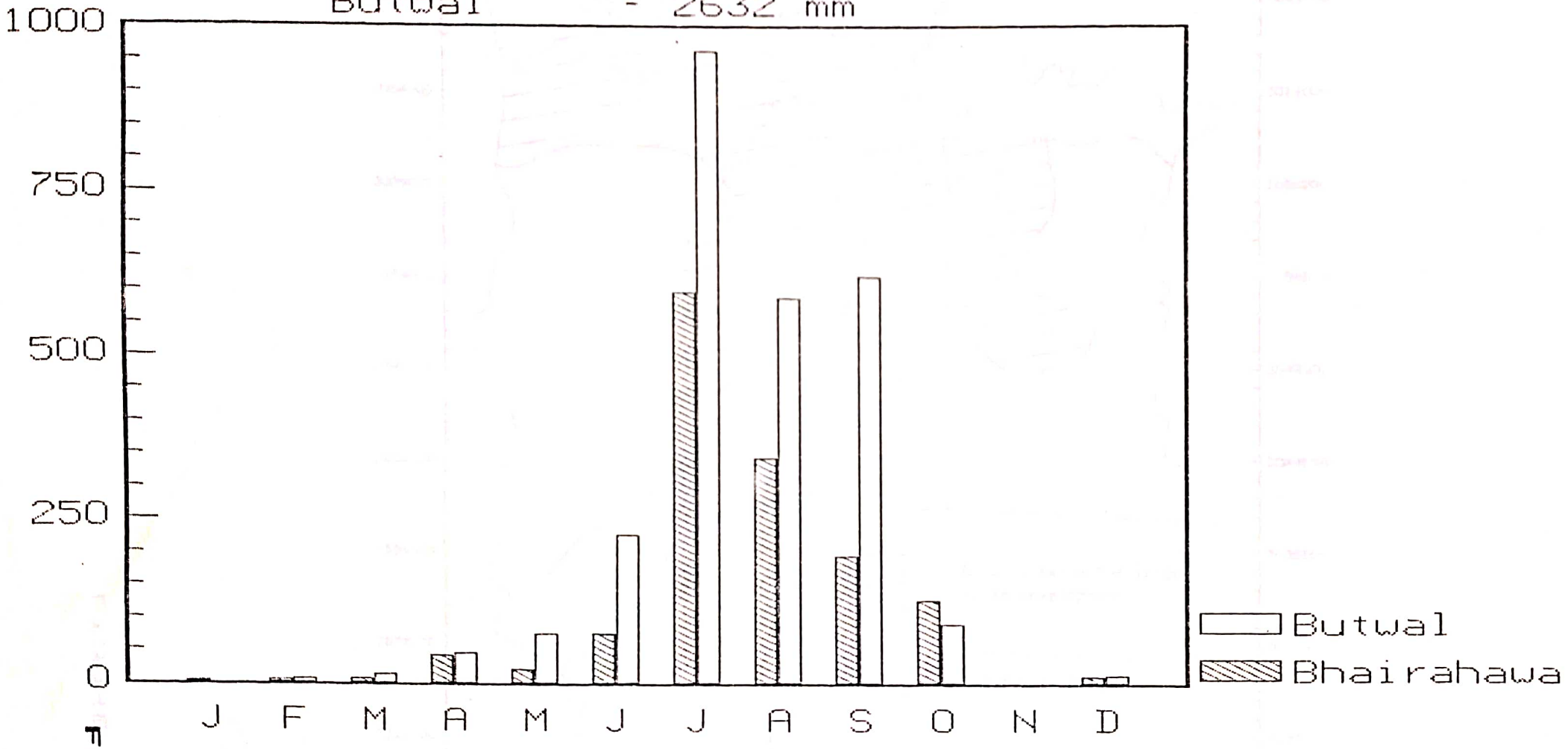


FIGURE 5

SHALLOW GROUND WATER DEVELOPMENT FEASIBILITY

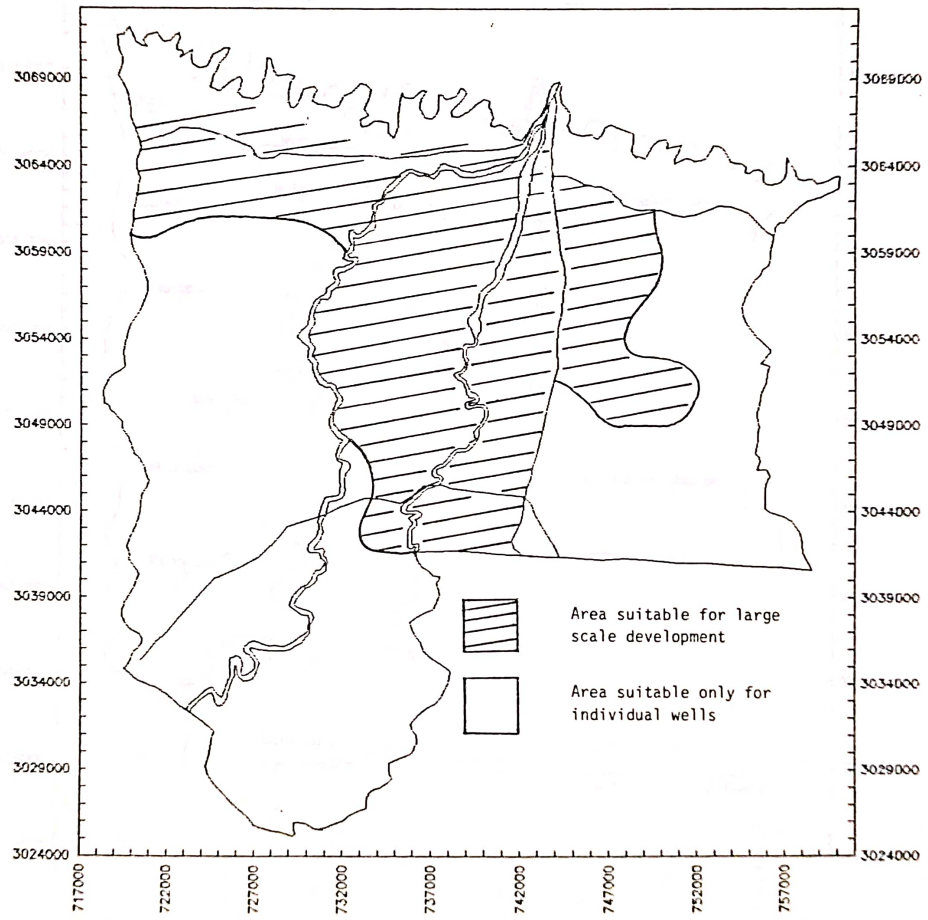
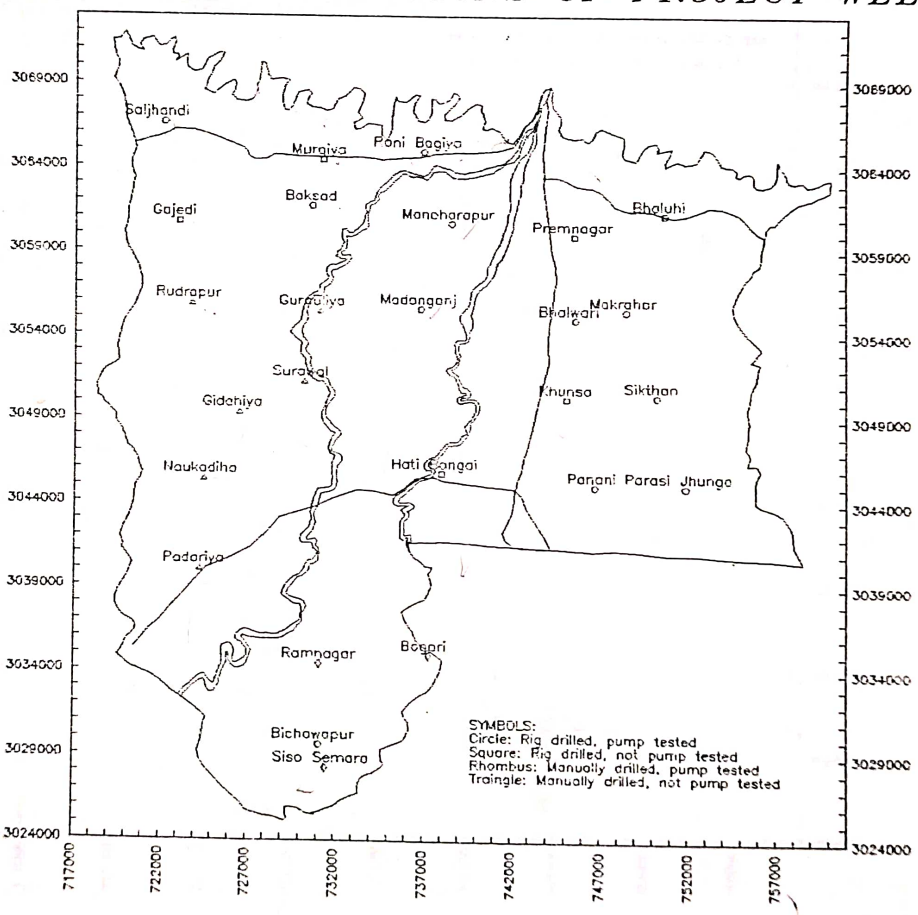


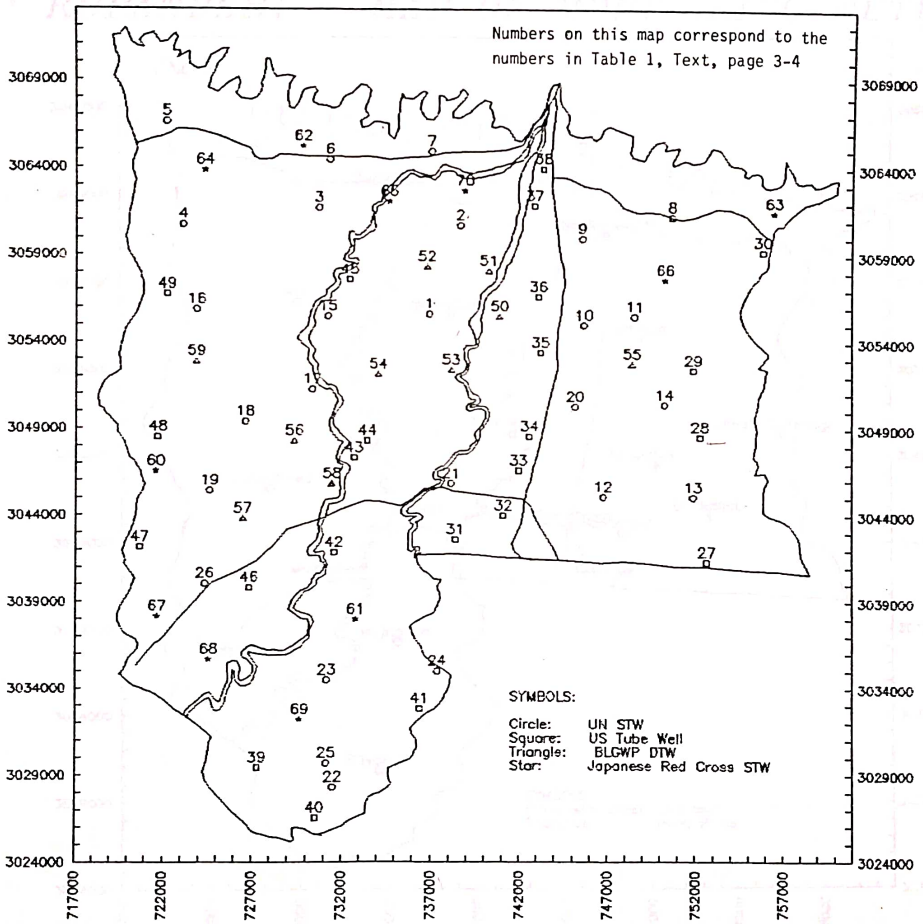
FIGURE 6

RUPANDEHI – LOCATIONS OF PROJECT WELLS



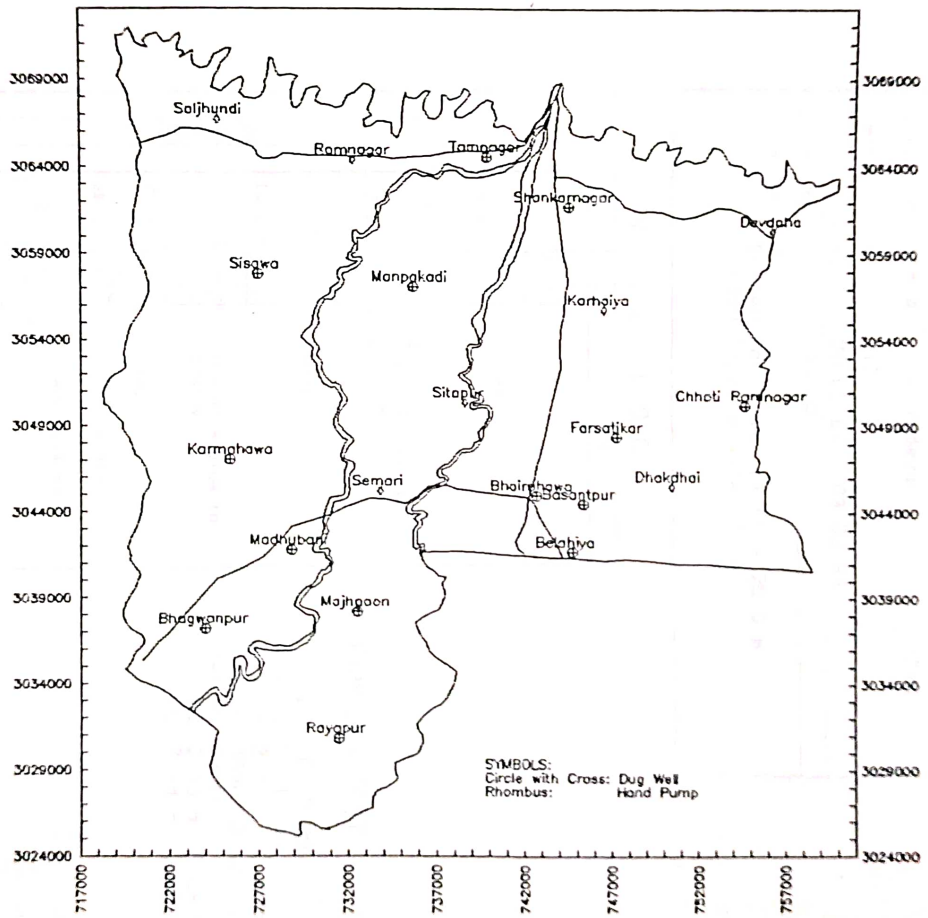
APPENDIX 1

RUPANDEHI – TUBE WELL LOCATION MAP



APPENDIX 1A

RUPANDEHI – MAP OF MONITORING NETWORK



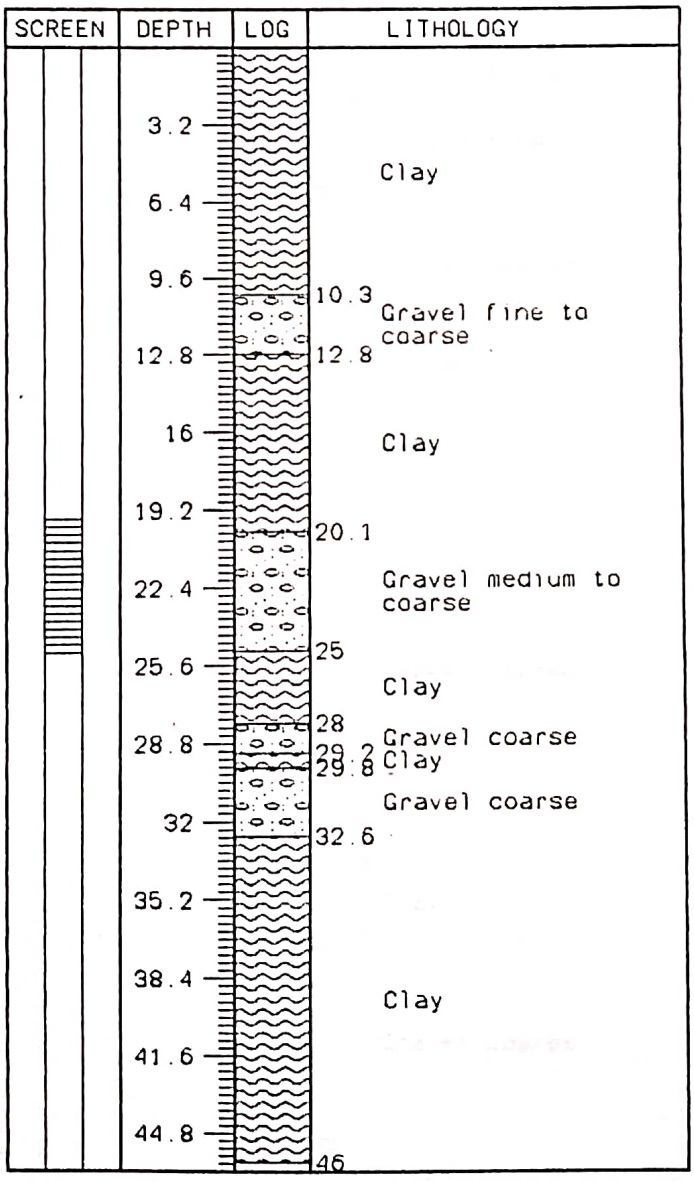
APPENDIX 2

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. UN 1	Location: MADANGANJ
Elevation: 116.4	X = 736875 Y = 3055625
Method of Drilling: RIG	
Drilling Dates : 29.01.89 - 03.02.89	
Total Depth : 46.00	
Comments : M.P: 0.56 m. Screen Position: 19.51 - 25.0 m. Screen Type: Slotted Pipe	

W E L L L O G



PUMPING TEST

Date: 10.02.89
Capacity: 12 l/sec
Duration: 3 hrs. 30 min.
Transmiss.: 3690 m2/day
Method : Jacob
SWL: 2.69 m.(B.GR.L)
DWL: 7.14 m.(B.GR.L)

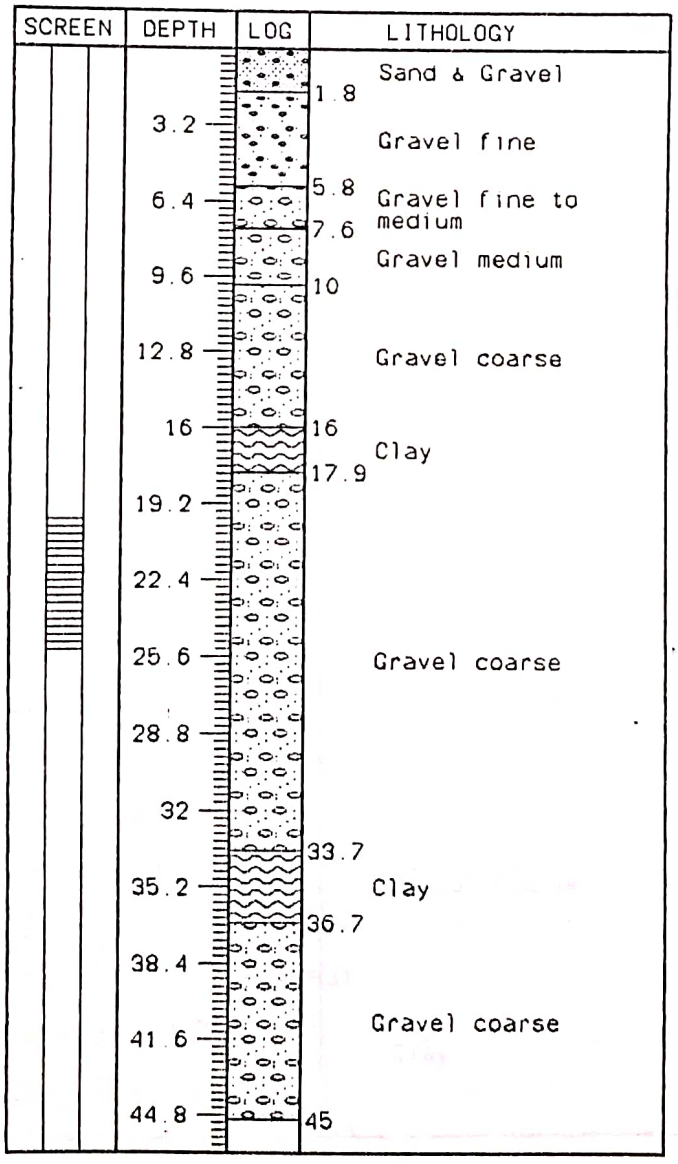
APPENDIX 3/1

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. UN 2	Location: MANOHARPUR
Elevation: 145.1	X = 738625 Y = 3060750
Method of Drilling: RIG	
Drilling Dates : 04.02.89 - 09.02.89	
Total Depth : 45.00	
Comments : M.P: 0.50 m. Screen Position: 19.81 - 25.31 m. Screen Type: Slotted Pipe	

W E L L L O G



PUMPING TEST

Date: 15.02.89
Capacity: 13.3 l/sec
Duration: 2 hrs.
Transmiss.: 6955 m2/day
Method : Jacob
SWL: 6.14 m.(B.GR.L)
DWL: 7.73 m.(B.GR.L)

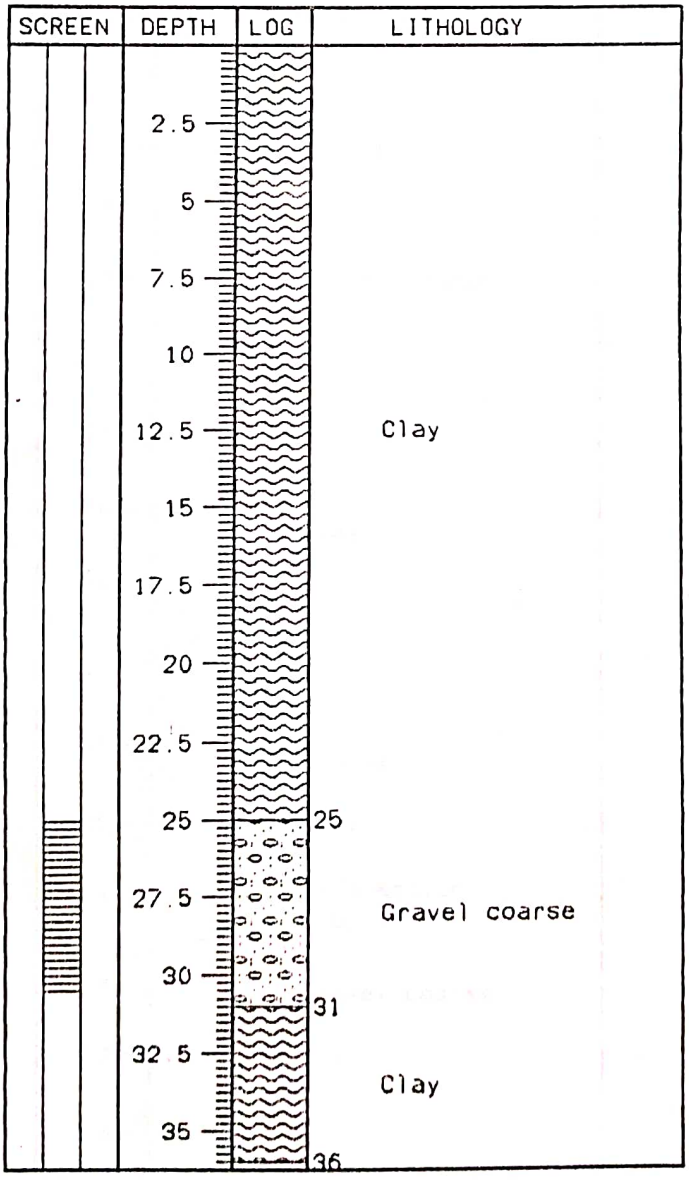
APPENDIX 3/2

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. UN 3	Location: BAKSAD
Elevation: 121	X = 730625 Y = 3061750
Method of Drilling: RIG	
Drilling Dates : 10.02.89 - 15.02.89	
Total Depth : 36.00	
Comments : M.P: 0.51 m. Screen Position: 25.0 - 30.5 m. Screen Type: Slotted Pipe	

W E L L L O G



PUMPING TEST

Date: 19.02.89
Capacity: 17 l/sec
Duration: 3 hrs.
Transmiss.: 1292 m2/day
Method : Jacob
SWL: 0.74 m.(A.GR.L)
DWL: 7.82 m.(B.GR.L)

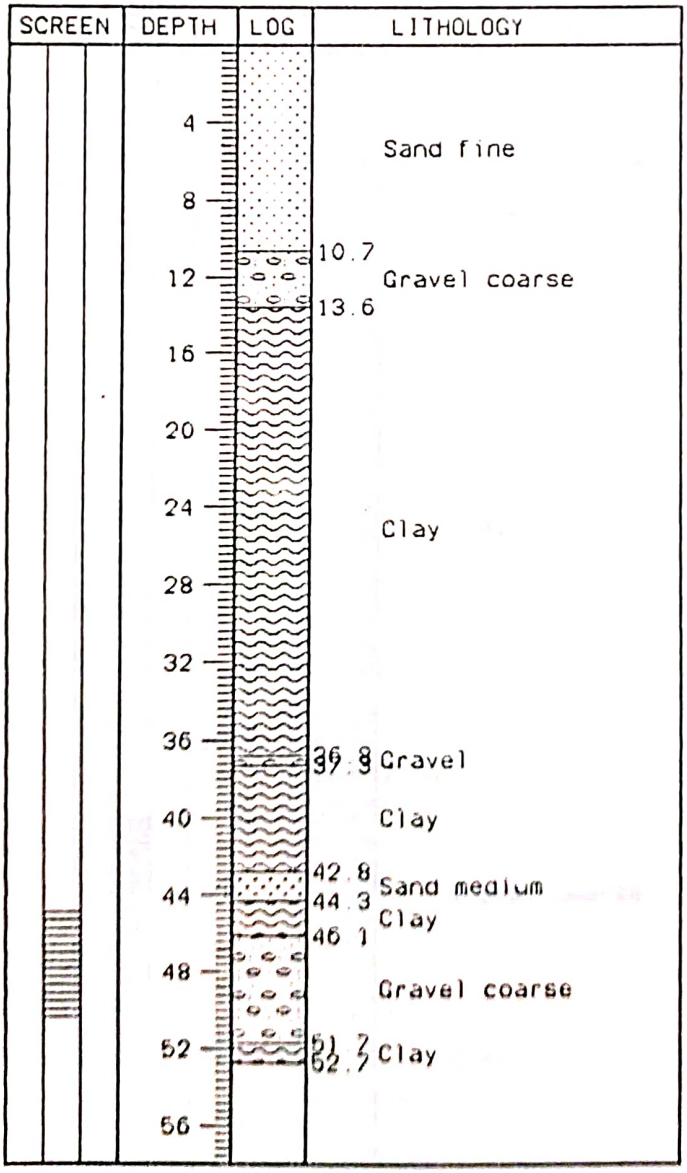
APPENDIX 3/3

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No UN 4	Location GAJEDI
Elevation 122.5	X = 723000 Y = 3060750
Method of Drilling	RIG
Drilling Dates	16.02.89 - 21.02.89
Total Depth	52.70
Comments	M.P: 0.30 m. Screen Position: 44.8 - 50.3 m. Screen Type: Slotted Pipe

W E L L L O G



PUMPING TEST

Capacity: 2.5 l/sec (flowing)
SWL: 4.03 m.(A.GR.L)

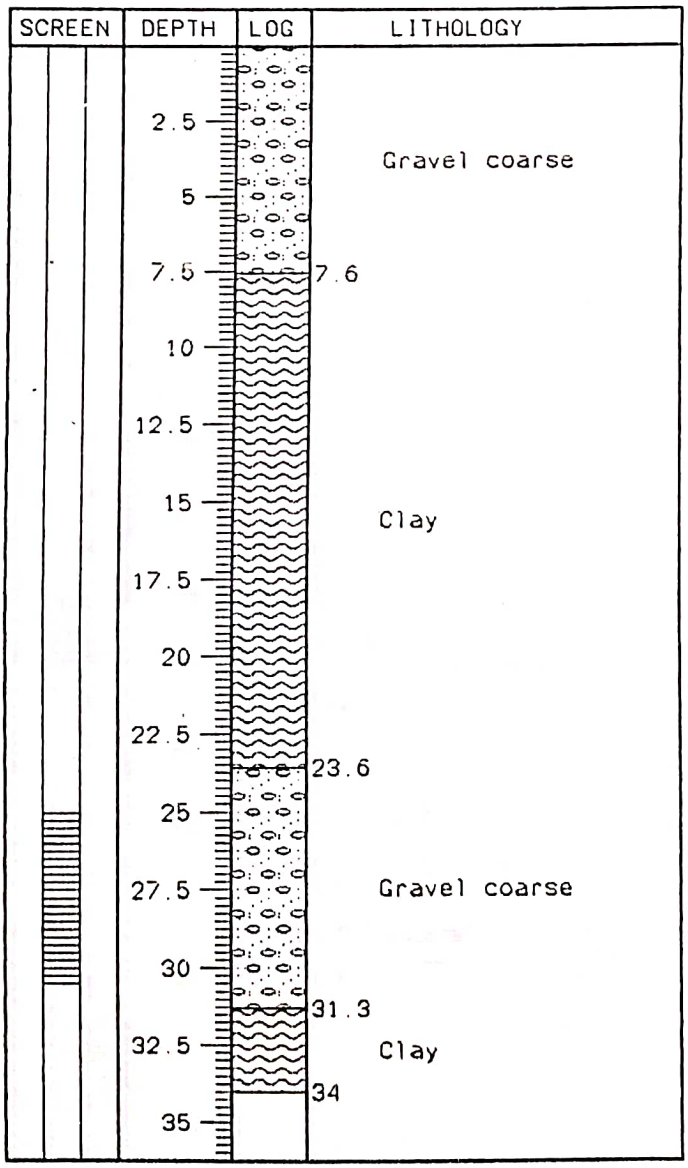
APPENDIX 3/4

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. UN 5	Location: SALJHANDI
Elevation: 152.4	X = 722125 Y = 3066625
Method of Drilling: RIG	
Drilling Dates : 22.02.89 - 27.02.89	
Total Depth : 34.00	
Comments : M.P: 0.52 m. Screen Position: 25.0 - 30.5 m. Screen Type: Slotted Pipe	

W E L L L O G



PUMPING TEST

Date: 10.04.89
Capacity: 24 l/sec
Duration: 3 hrs.
Transmiss.: 2955 m2/day
Method : Jacob
SWL: 2.58 m.(B.GR.L)
DWL: 6.30 m.(B.GR.L)

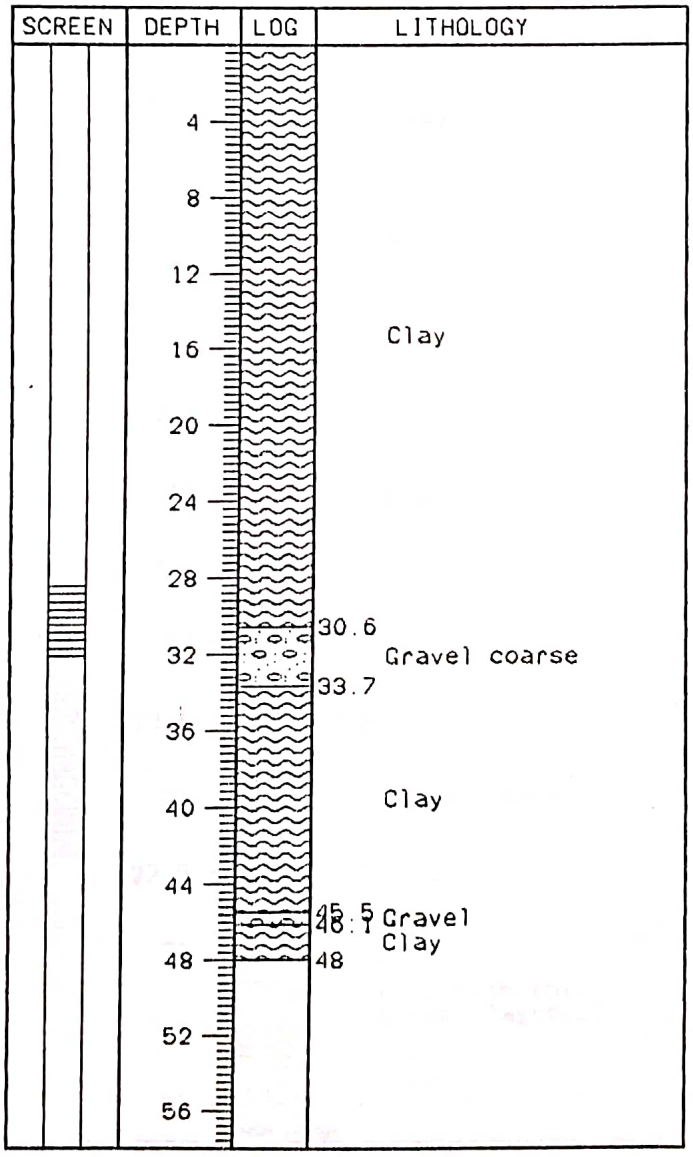
APPENDIX 3/5

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. UN 6	Location: MURGIYA
Elevation: 141.7	X = 731250 Y = 3064500
Method of Drilling: RIG	
Drilling Dates : 28.02.89 - 05.03.89	
Total Depth : 48.00	
Comments : M.P: 0.50 m. Screen Position: 28.35 - 32.0 m. Screen Type: Slotted Pipe	

W E L L L O G



PUMPING TEST

SWL: 3.95 m.(B.GR.L)

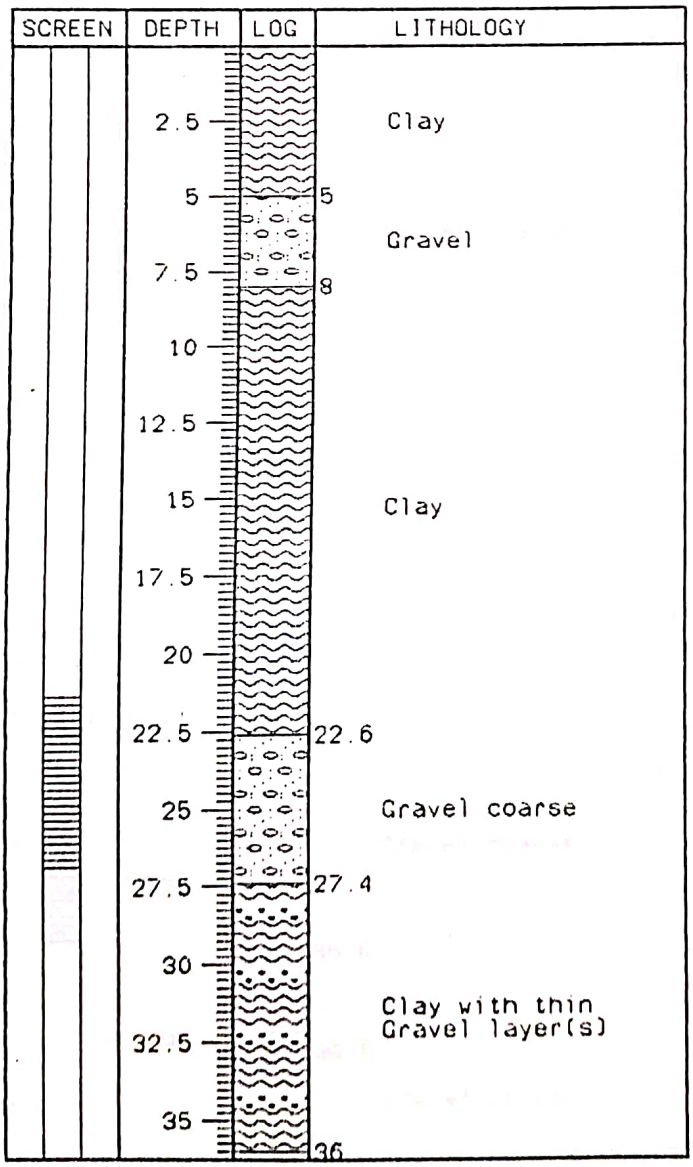
APPENDIX 3/6

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. UN 7	Location: RANI BAGIYA
Elevation: 146.3	X = 737000 Y = 3065000
Method of Drilling: RIG	
Drilling Dates : 06.03.89 - 11.03.89	
Total Depth : 36.00	
Comments : M.P: 0.45 m. Screen Position: 21.34 - 26.84 m. Screen Type: Slotted Pipe	

W E L L L O G



PUMPING TEST

Date: 15.03.89
Capacity: 17 l/sec
Duration: 3 hrs.
Transmiss.: 785 m2/day
Method : Jacob
SWL: 1.19 m.(B.GR.L)
DWL: 7.49 m.(B.GR.L)

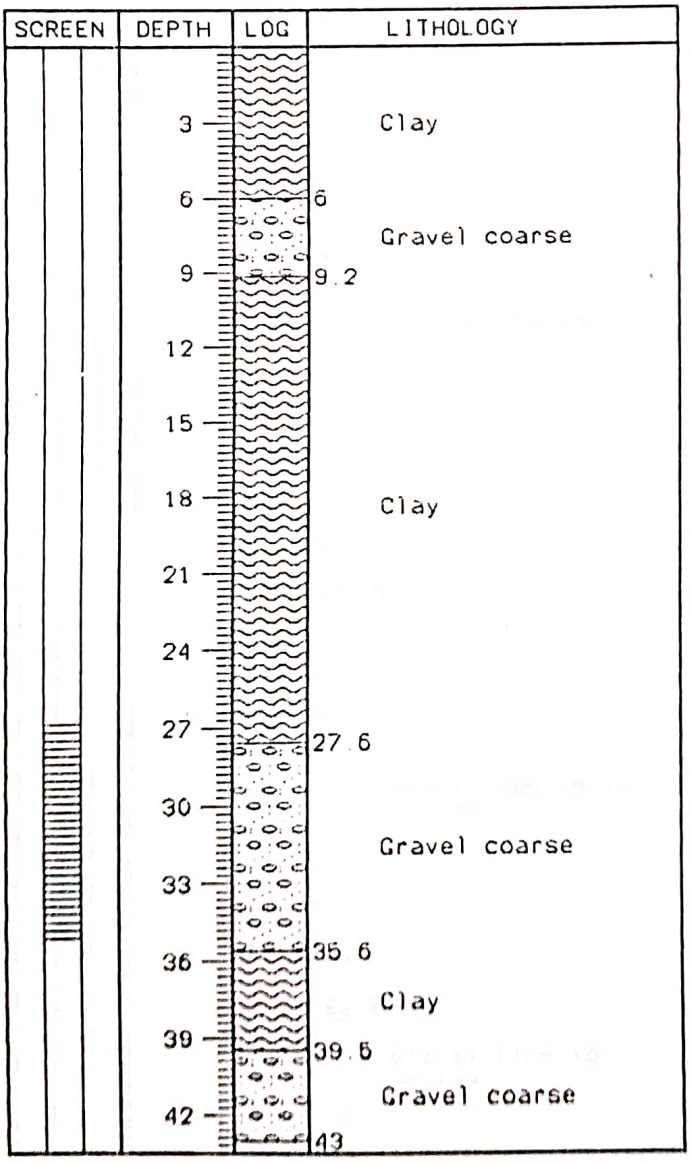
APPENDIX 3/7

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. UN 8	Location: BHALUHI
Elevation: 130.2	X = 750750 Y = 3061250
Method of Drilling: RIG	
Drilling Dates : 12.03.89 - 17.03.89	
Total Depth : 43.00	
Comments : M.P: 0.53 m. Screen Position: 26.81 - 35.06 m. Screen Type: Slotted Pipe	

W E L L L O G



PUMPING TEST

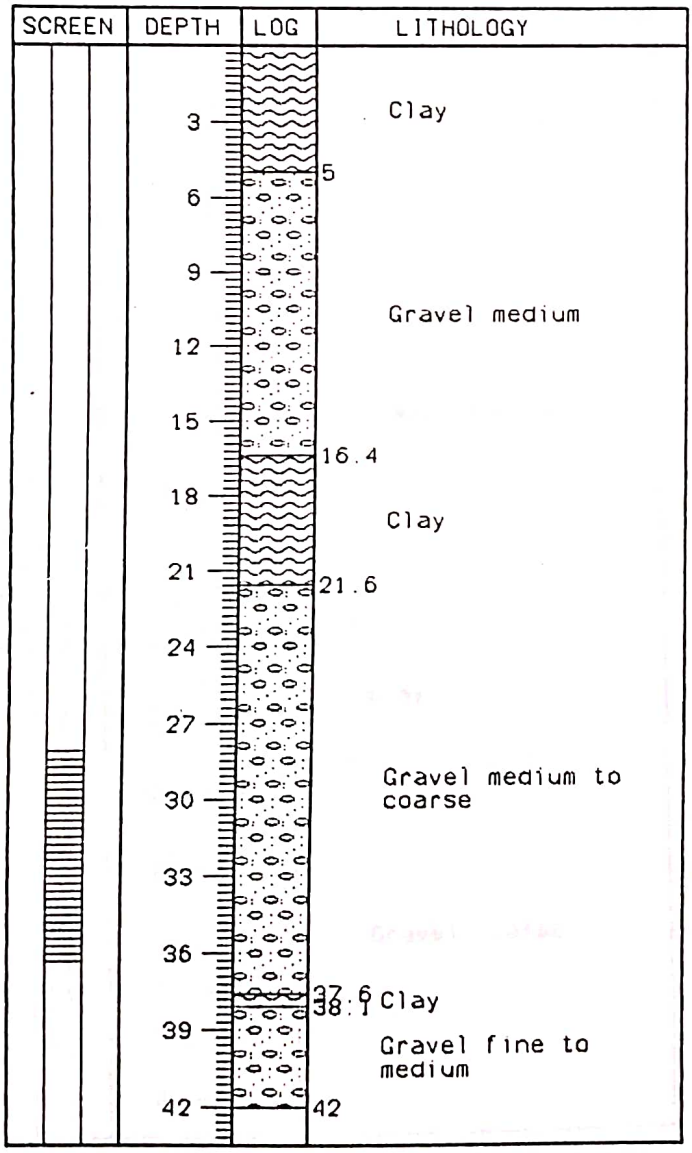
Date: 23.03.89
Capacity: 17 l/sec
Duration: 3 hrs. 30 min.
Transmiss.: 550 m2/day
Method: Jacob
SWL: 1.26 m.(A.GR.L)
DWL: 5.01 m.(B.GR.L)

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. UN 9	Location: PREMNAGAR
Elevation: 143.3	X = 745625 Y = 3060000
Method of Drilling:	RIG
Drilling Dates :	18.03.89 - 20.03.89
Total Depth :	42.00
Comments :	M.P: 0.30 m. Screen Position: 28.04 - 36.29 m. Screen Type: Slotted Pipe

W E L L L O G



PUMPING TEST

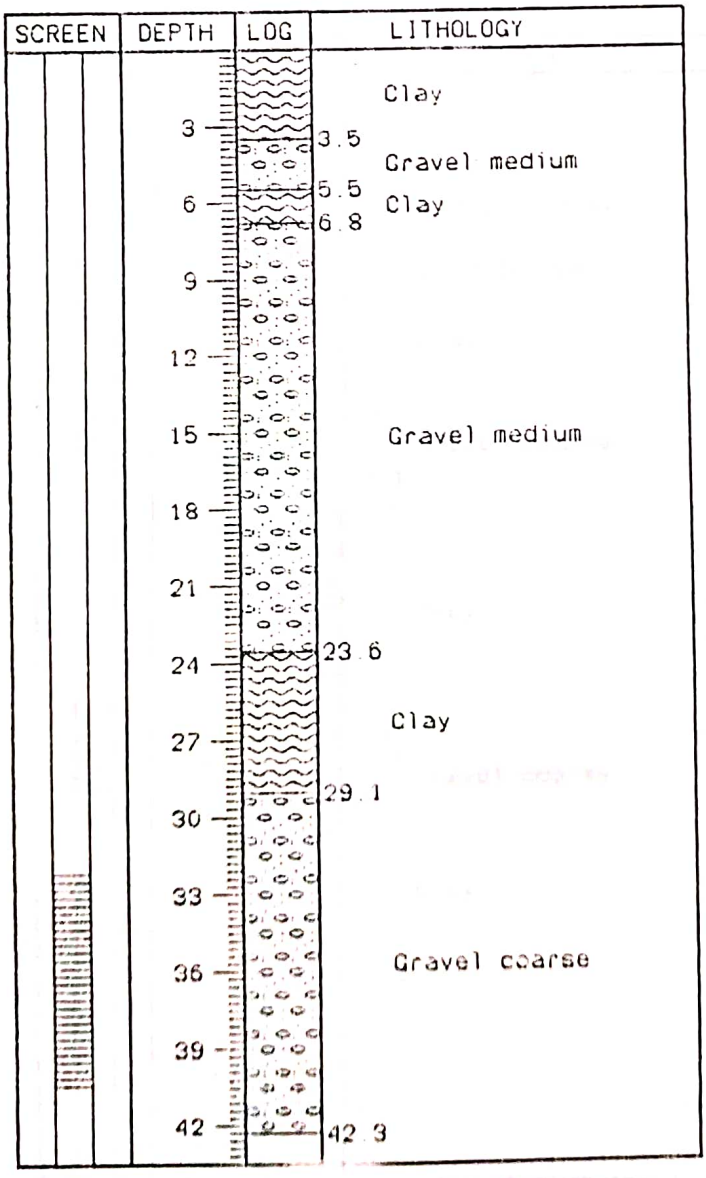
SWL: 9.47 m.(B.GR.L)

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. UN 10	Location: BHALWARI
Elevation: 121	X = 745750 Y = 3055000
Method of Drilling:	RIG
Drilling Dates :	23.03.89 - 24.03.89
Total Depth :	42.30
Comments :	M.P: 0.50 m. Screen Position: 32.14 - 40.39 m. Screen Type: Slotted Pipe

W E L L L O G



PUMPING TEST

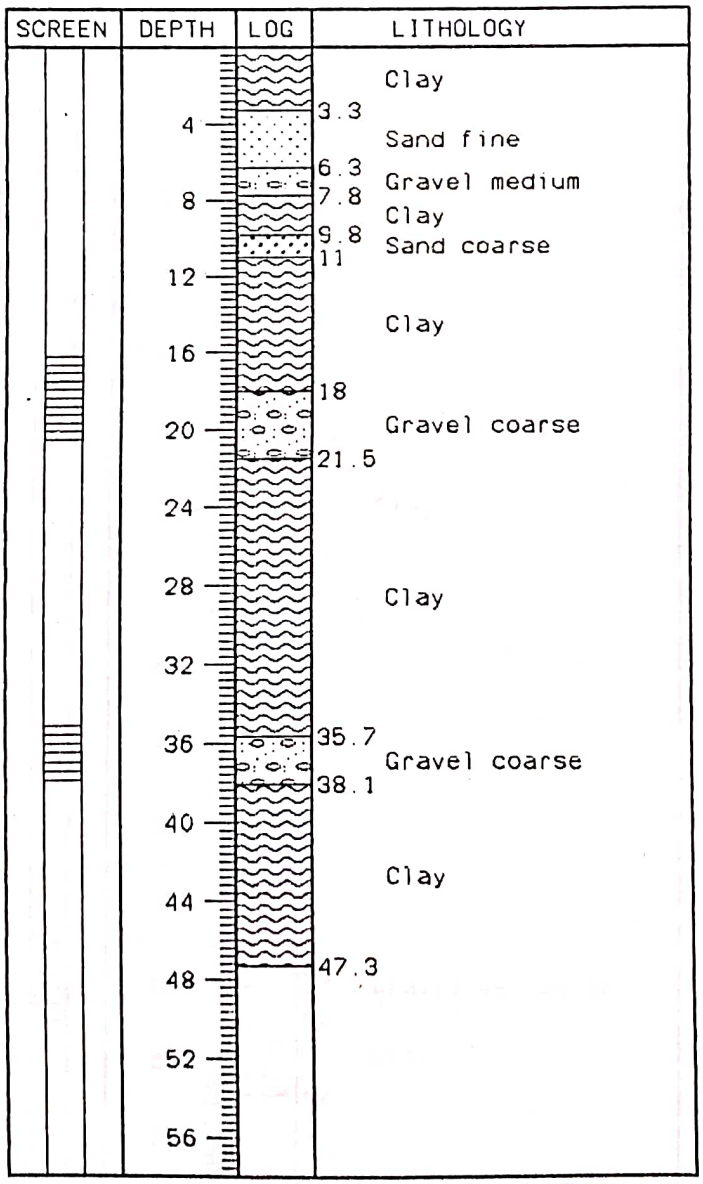
Date: 28.03.89
Capacity: 24 l/sec
Duration: 3 hrs.
Transmiss.: 2585 m2/day
Method : Jacob
SWL: 0.04 m.(A.GR.L)
DWL: 3.71 m.(B.GR.L)

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. UN 11	Location: MAKRAHAR
Elevation: 123.1	X = 748625 Y = 3055500
Method of Drilling: RIG	
Drilling Dates : 27.03.89 - 28.03.89	
Total Depth : 47.30	
Comments : M.P: 0.47 m. Screen Position: 16.16 - 20.43 m. 35.06 - 37.81 m. Screen Type: Slotted Pipe	

W E L L L O G



PUMPING TEST

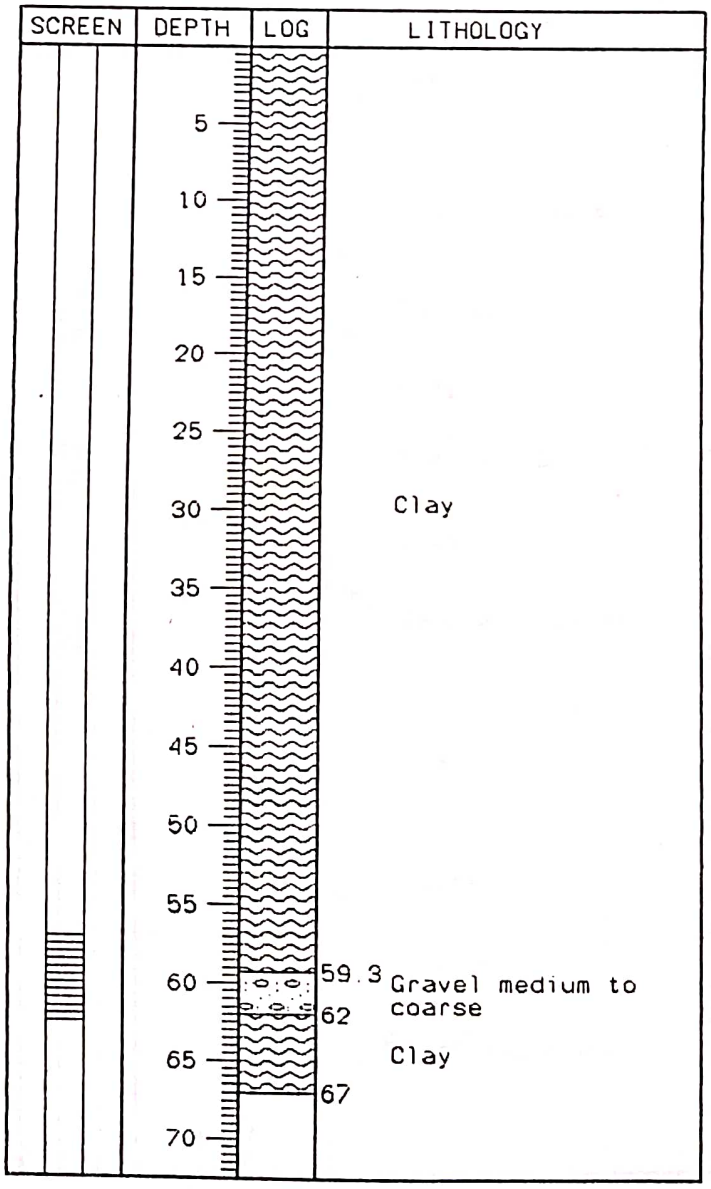
Date: 02.04.89
Capacity: 20 l/sec
Duration: 3 hrs.
Transmiss.: 655 m2/day
Method : Jacob
SWL: 1.08 m.(B.GR.L)
DWL: 5.73 m.(B.GR.L)

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. UN 12	Location: PANANI
Elevation: 108.2	X = 746875 Y = 3045000
Method of Drilling: RIG	
Drilling Dates : 30.03.89 - 01.04.89	
Total Depth : 67.00	
Comments : M.P: 0.50 m. Screen Position: 57 - 62.5 m. Screen Type: Slotted Pipe	

W E L L L O G



PUMPING TEST

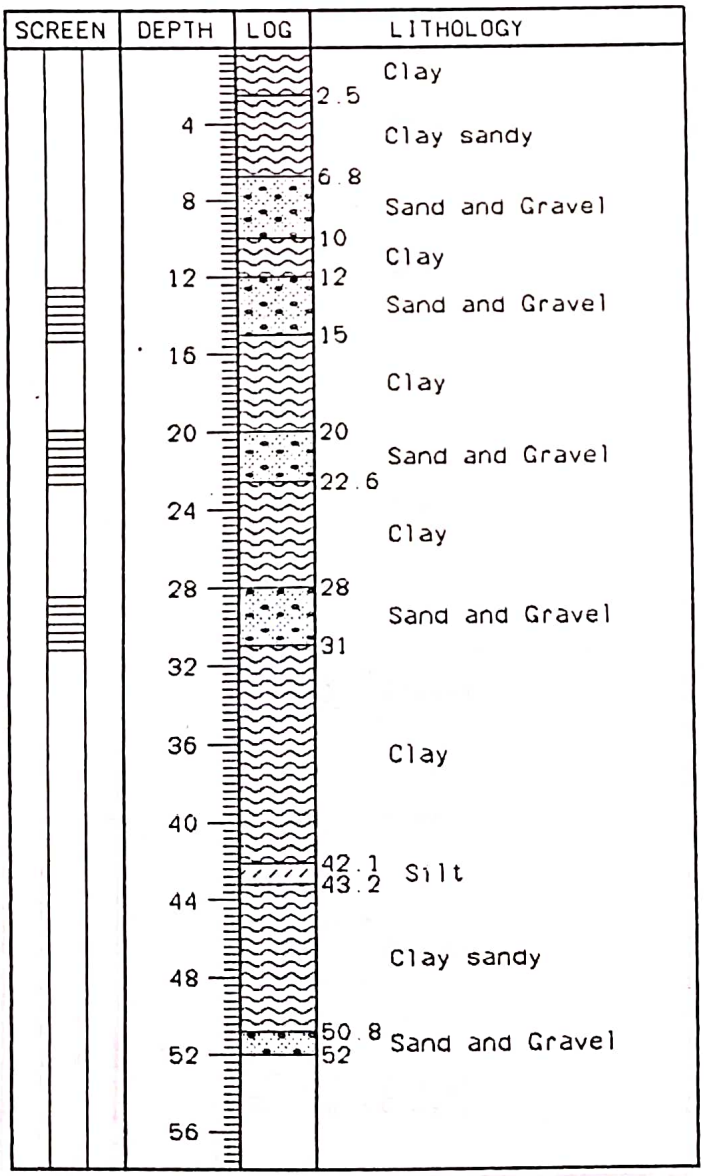
Date: 08.04.89
Capacity: 6 l/sec
Duration: 3 hrs.
Transmiss.: 285 m2/day
Method : Jacob
SWL: 1.28 m.(B.GR.L)
DWL: 5.79 m.(B.GR.L)

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. UN 13	Location: PARASI JHUNGA
Elevation: 109.7	X = 752000 Y = 3045000
Method of Drilling: RIG	
Drilling Dates : 05.04.89 - 06.04.89	
Total Depth : 52.00	
Comments : M.P: 0.55 m. Screen Position: 12.50 - 15.25 m. 19.81 - 22.56 m. 28.35 - 31.10 m. Screen Type: Slotted Pipe	

W E L L L O G



PUMPING TEST

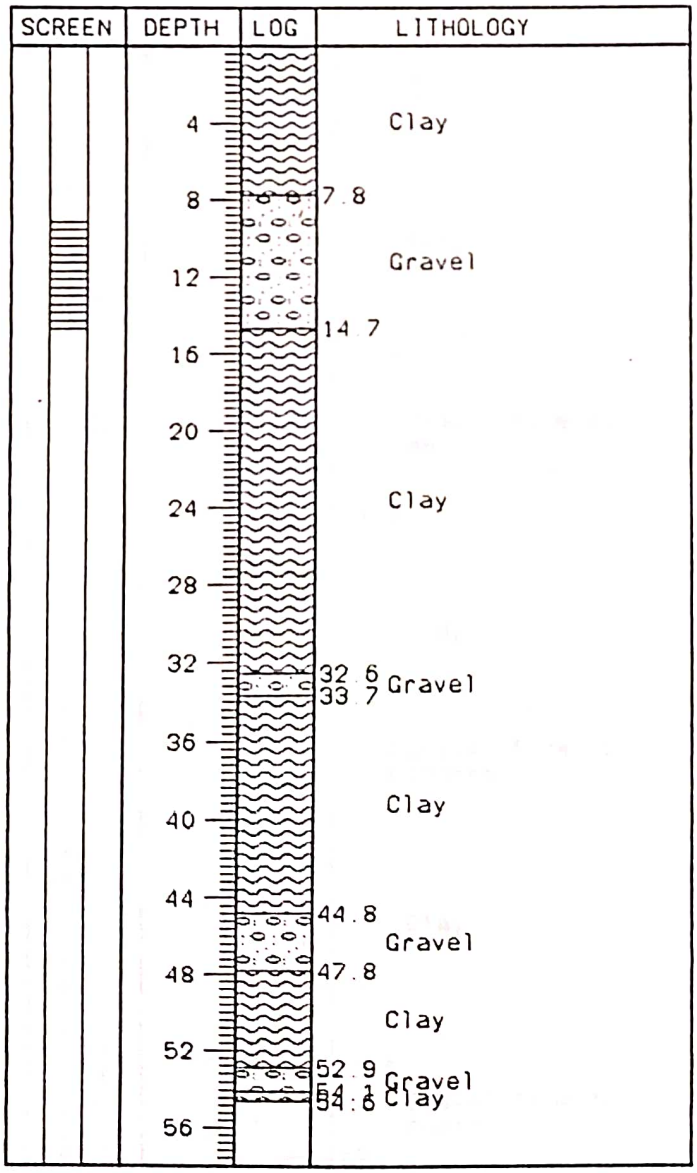
Capacity: 2 l/sec
Duration: 3 hrs.
Transmiss.: 45 m2/day
Method : Jacob
SWL: 2.68 m.(B.GR.L)
DWL: 7.81 m.(B.GR.L)

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. UN 14	Location: SIKTHAN
Elevation: 117.6	X = 750375 Y = 3050375
Method of Drilling: RIG	
Drilling Dates : 10.04.89 - 12.04.89	
Total Depth : 54.60	
Comments : M.P: 0.58 m. Screen Position: 9.14 - 14.64 m. Screen Type: Slotted Pipe	

W E L L L O G



PUMPING TEST

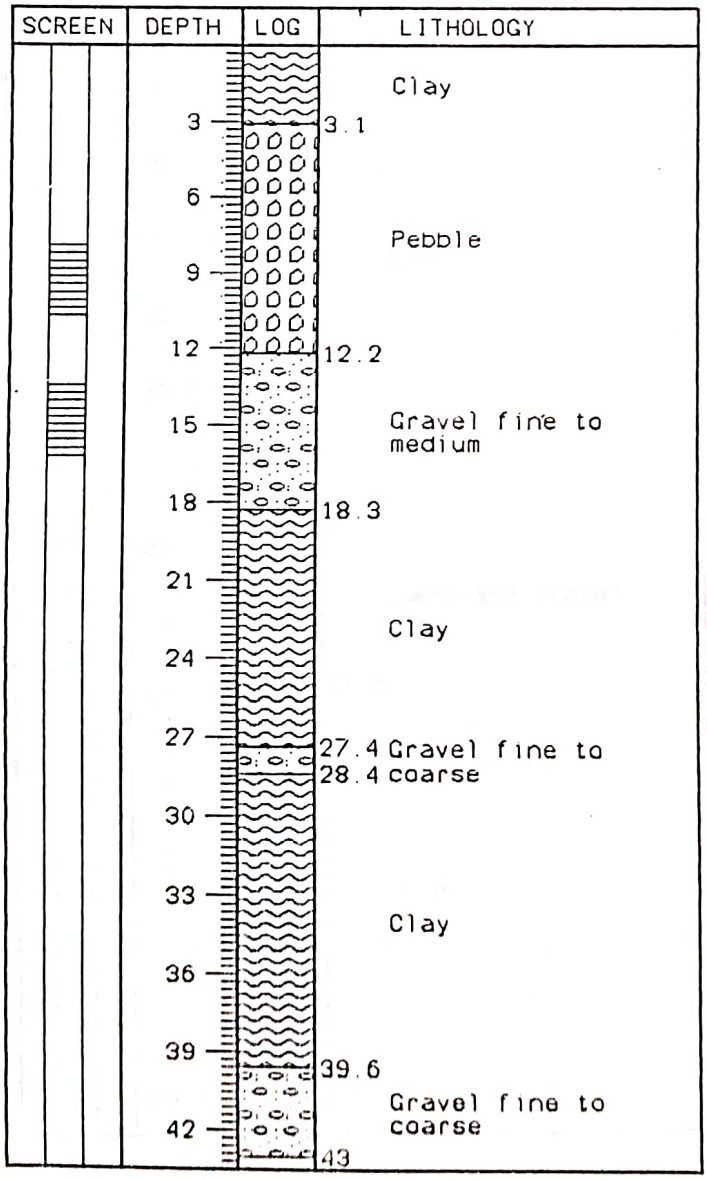
Date: 17.04.89
Capacity: 7.5 l/sec
Duration: 3 hrs.
Transmiss.: 1815 m2/day
Method : Jacob
SWL: 7.19 m.(B.GR.L)
DWL: 8.51 m.(B.GR.L)

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. UN 15	Location: GURAULIYA
Elevation: 114	X = 731125 Y = 3055500
Method of Drilling: MANUAL	
Drilling Dates : 27.04.89 - 03.05.89	
Total Depth : 43.00	
Comments : M.P: 0.30 m. Screen Position: 7.93 - 10.68 m. 13.42 - 16.17 m. Screen Type: Slotted Pipe	

W E L L L O G

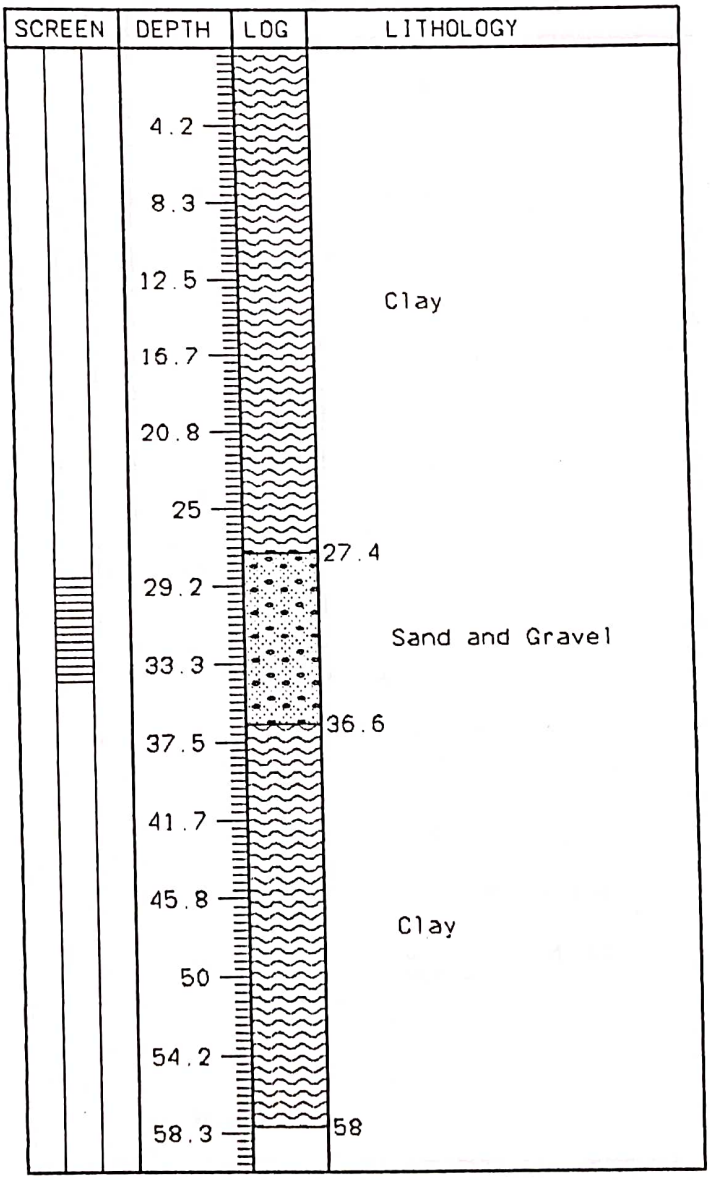


GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

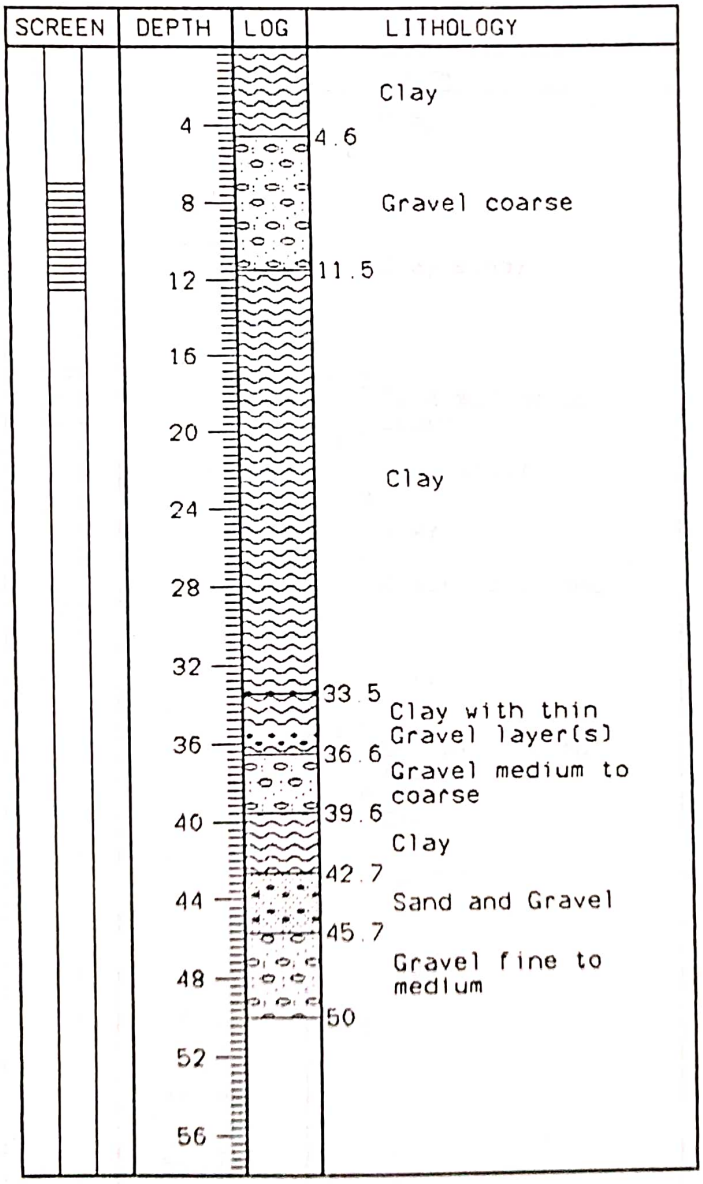
Well No. UN 16	Location: RUDRAPUR
Elevation: 109.7	X = 723750 Y = 3055875
Method of Drilling:	MANUAL
Drilling Dates :	27.04.89 - 03.05.89
Total Depth :	58.00
Comments :	M.P: 0.30 m. Screen Position: 28.66 - 34.16 m. Screen Type: Slotted Pipe

W E L L L O G



Well No. UN 17	Location: SURAWAL
Elevation: 106.4	X = 730250 Y = 3051250
Method of Drilling:	MANUAL
Drilling Dates	12.05.89 - 19.05.89
Total Depth	50.00
Comments :	M.P: 0.30 m. Screen Position: 7.0 - 12.5 m. Screen Type: Slotted Pipe

W E L L L O G

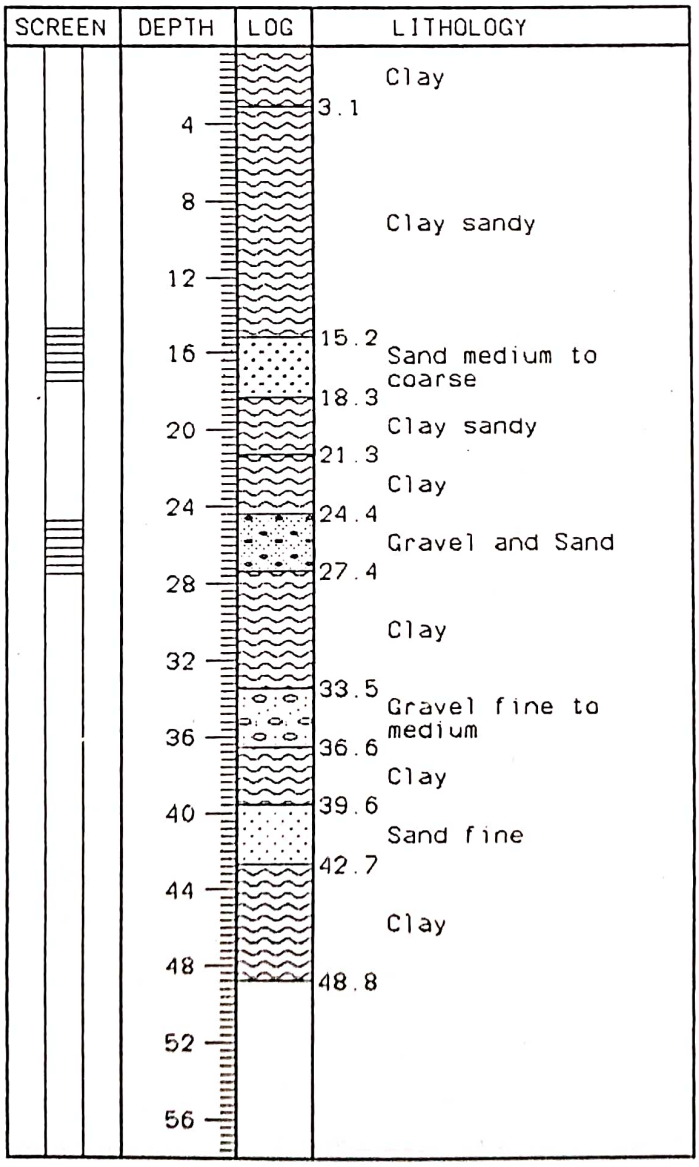


GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. UN 18	Location: GIDAHIYA
Elevation: 105.2	X = 726500 Y = 3049375
Method of Drilling:	MANUAL
Drilling Dates :	12.05.89 - 19.05.89
Total Depth :	48.80
Comments :	M.P: 0.30 m. Screen Position: 14.62 - 17.37 m. 24.68 - 27.43 m. Screen Type: Slotted Pipe

W E L L L O G

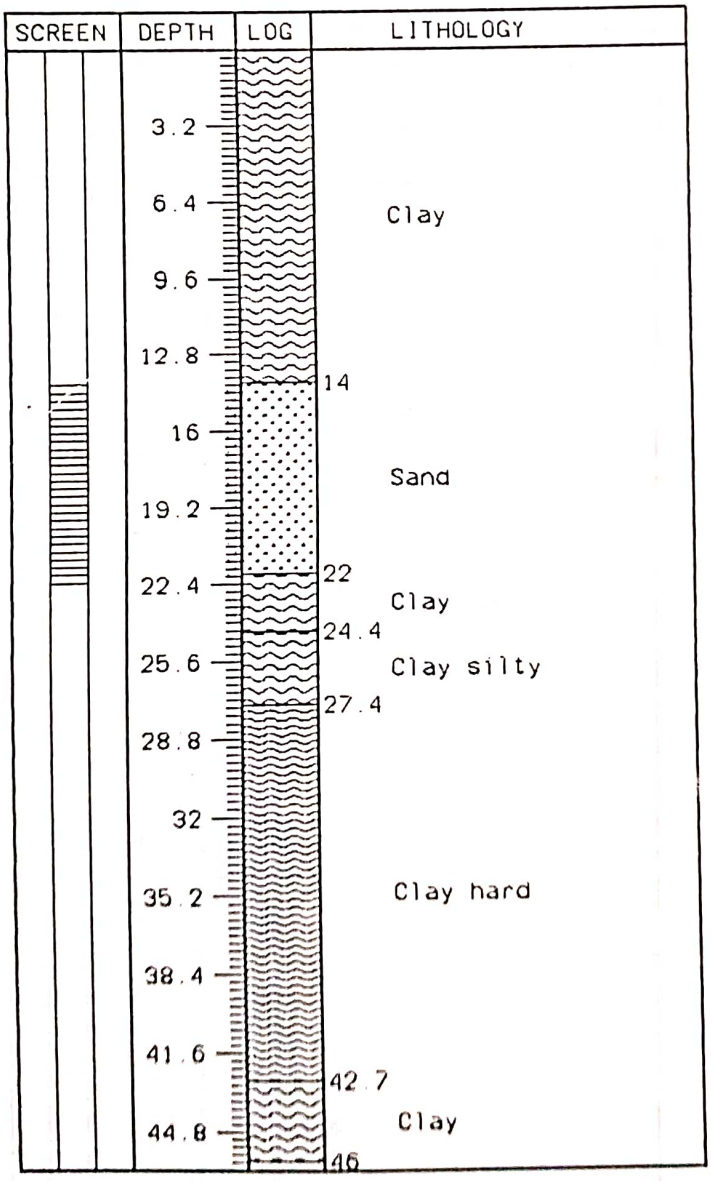


GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. UN 19	Location: NAUKADIHA
Elevation: 103.6	X = 724500 Y = 3045375
Method of Drilling: MANUAL	
Drilling Dates : 12.05.89 - 19.05.89	
Total Depth : 46.00	
Comments : M.P: 0.50 m. Screen Position: 14.02 - 22.27 m. Screen Type: Slotted Pipe	

W E L L L O G

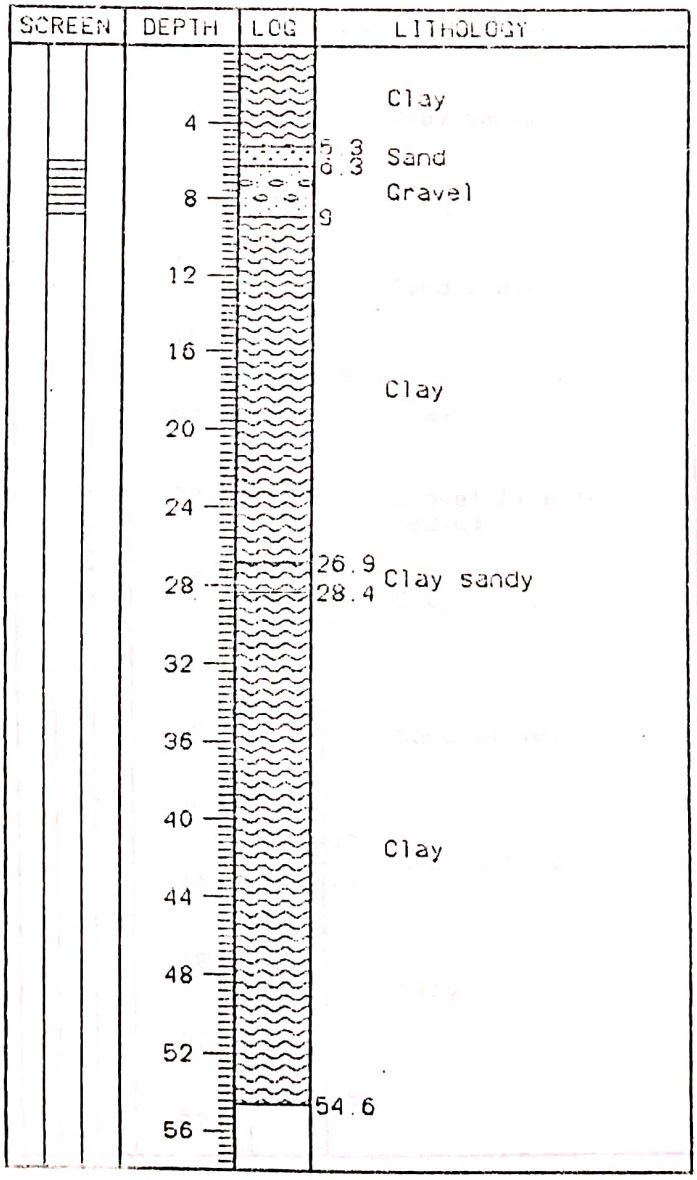


GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. UN 20	Location: KHUNSA
Elevation: 116.4	X = 745250 Y = 3050250
Method of Drilling: RIG	
Drilling Dates : 16.05.89 - 21.05.89	
Total Depth : 54.60	
Comments : M.P: 0.35 m. Screen Position: 6.09 - 8.84 m. Screen Type: Slotted Pipe	

W E L L L O G

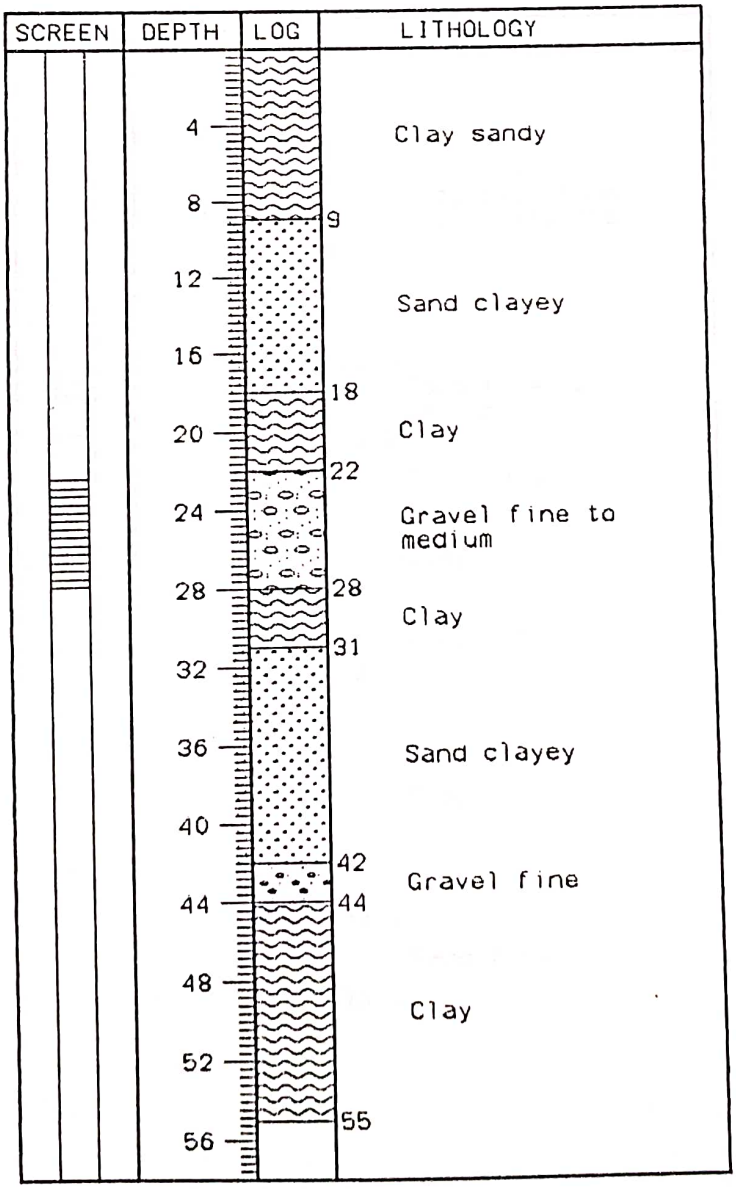


GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. UN 21	Location: HATI BANGAI
Elevation: 106.7	X = 738125 Y = 3045750
Method of Drilling: RIG	
Drilling Dates : 22.05.89 - 27.05.89	
Total Depth : 55.00	
Comments : M.P: 0.50 m. Screen Position: 22.25 - 27.73 m. Screen Type: Slotted Pipe	

W E L L L O G

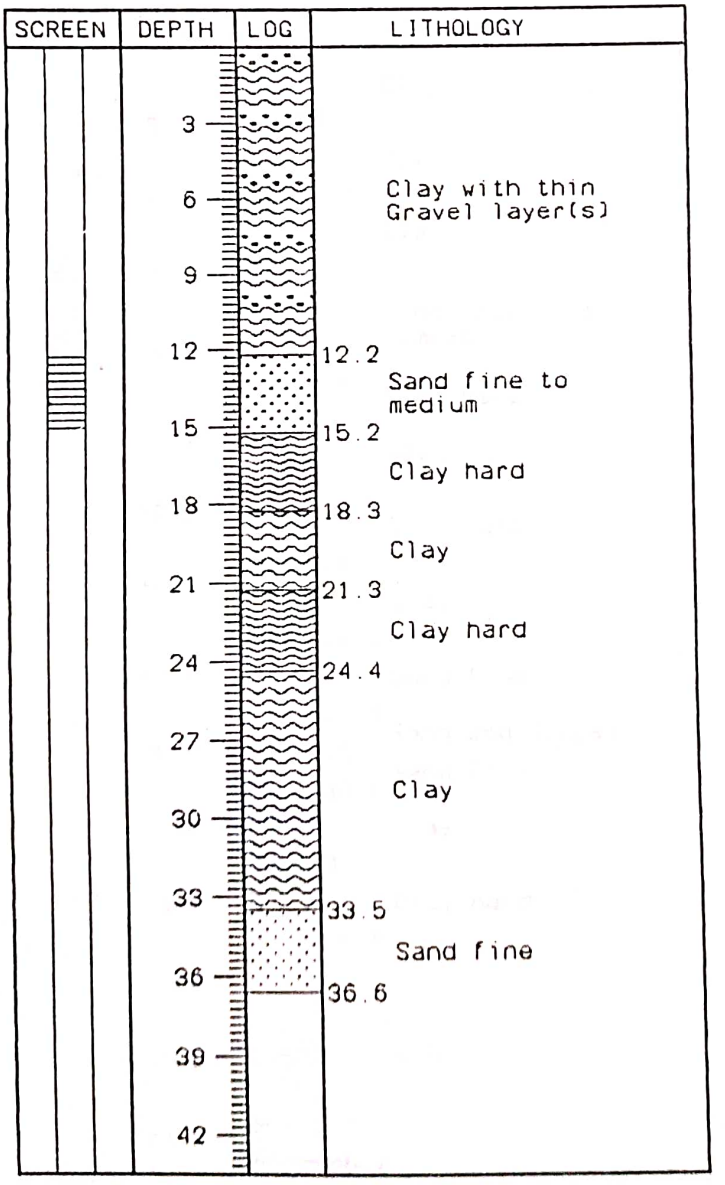


GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. UN 22	Location: SISO SEMARA
Elevation: 90.5	X = 731500 Y = 3028250
Method of Drilling: MANUAL	
Drilling Dates : 21.05.89 - ?	
Total Depth : 36.60	
Comments : M.P: 0.70 m. Screen Position: 12.20 - 14.95 m. Screen Type: Slotted Pipe	

W E L L L O G



PUMPING TEST

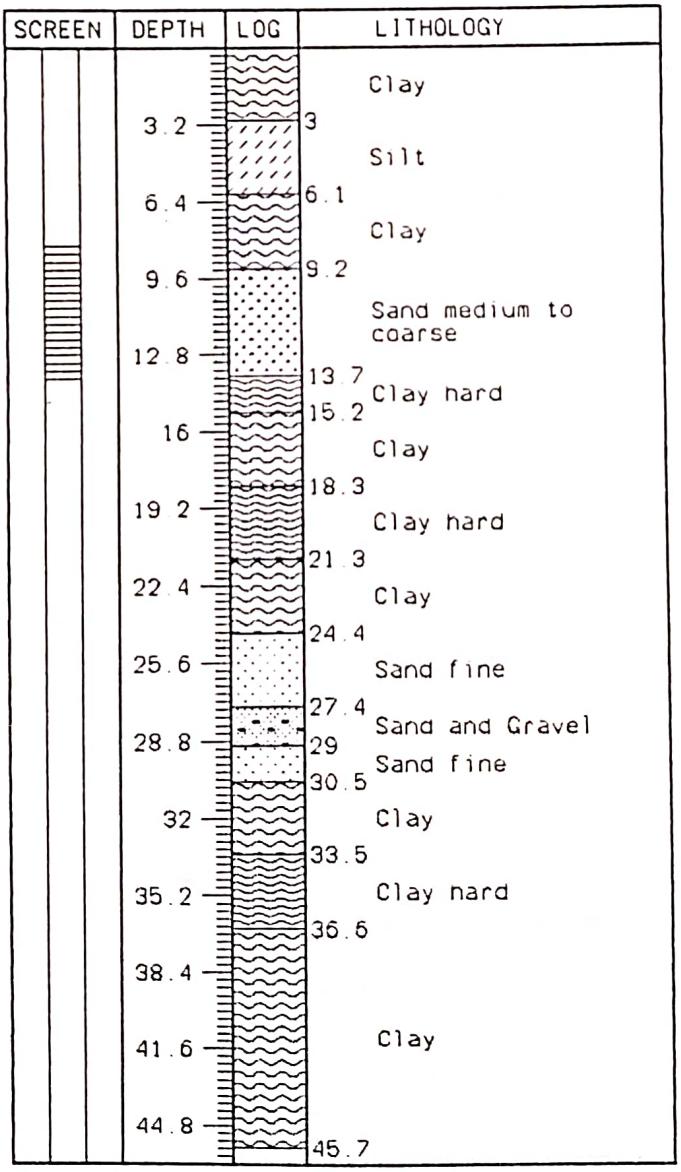
Capacity: 1.5 l/sec
Duration: 4 min.
Transmiss.: 210 m2/day
Method : Jacob
SWL: 3.84 m.(B.GR.L)
DWL: 7.82 m.(B.GR.L)

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. UN 23	Location: RAMNAGAR
Elevation: 96	X = 731125 Y = 3034375
Method of Drilling: MANUAL	
Drilling Dates : 22.06.89 - 29.06.89	
Total Depth : 45.70	
Comments : M.P: 0.41 m. Screen Position: 8.23 - 13.73 m. Screen Type: Slotted Pipe	

W E L L L O G



PUMPING TEST

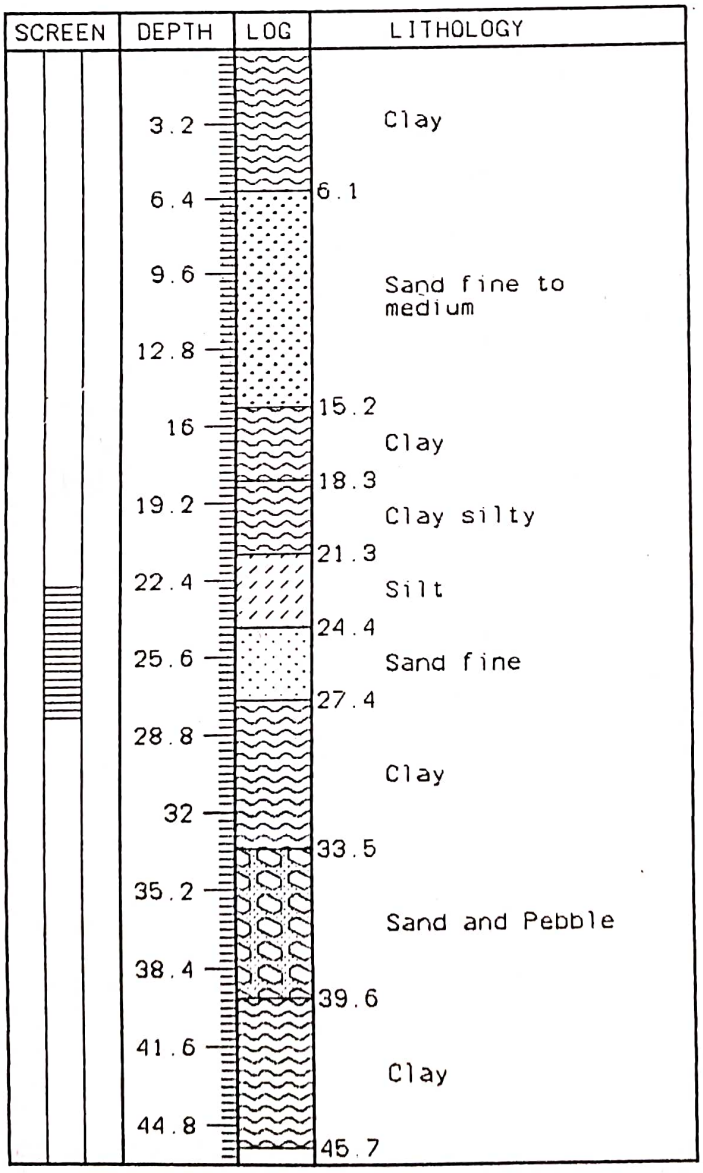
Capacity: 7.5 l/sec
Duration: 16 min.
Transmiss.: 590 m2/day
Method : Jacob
SWL: 3.17 m.(B.GR.L)
DWL: 8.43 m.(B.GR.L)

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. UN 24	Location: BOGARI
Elevation: 97.2	X = 737375 Y = 3034875
Method of Drilling:	MANUAL
Drilling Dates :	22.06.89 - 29.06.89
Total Depth :	45.70
Comments :	M.P: 0.65 m. Screen Position: 22.56 - 28.06 m. Screen Type: Slotted Pipe

W E L L L O G



PUMPING TEST

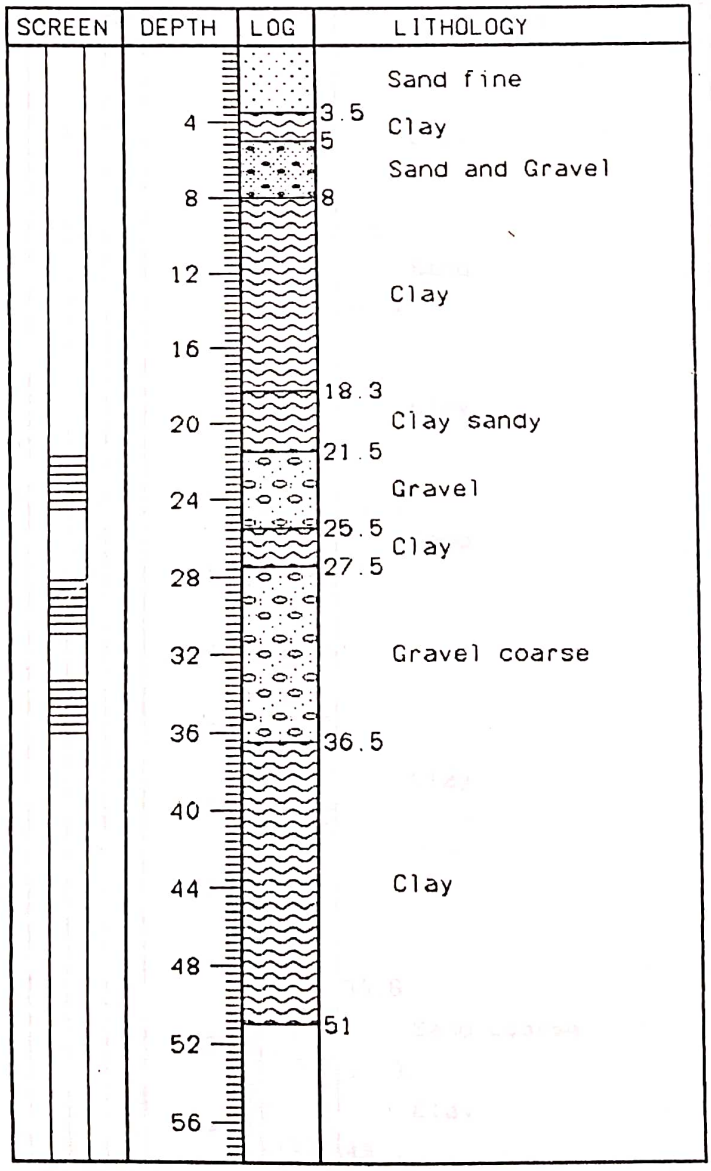
Capacity: 1.5 l/sec
Duration: 6 min.
Transmiss.: 140 m2/day
Method : Jacob
SWL: 3.41 m.(B.GR.L)
DWL: 8.30 m.(B.GR.L)

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. UN 25	Location: BICHAWAPUR
Elevation: 92.1	X = 731125 Y = 3029625
Method of Drilling: RIG	
Drilling Dates : 02.07.89 - 07.07.89	
Total Depth : 51.00	
Comments : M.P: 0.63 m. Screen Position: 21.65 - 24.40 m. 28.05 - 30.80 m. 33.23 - 35.98 m. Screen Type: Slotted Pipe	

W E L L L O G



PUMPING TEST

Capacity: 3.5 l/sec
Duration: 30 min.
Transmiss.: 140 m2/day
Method : Jacob
SWL: 1.82 m.(B.GR.L)
DWL: 7.12 m.(B.GR.L)

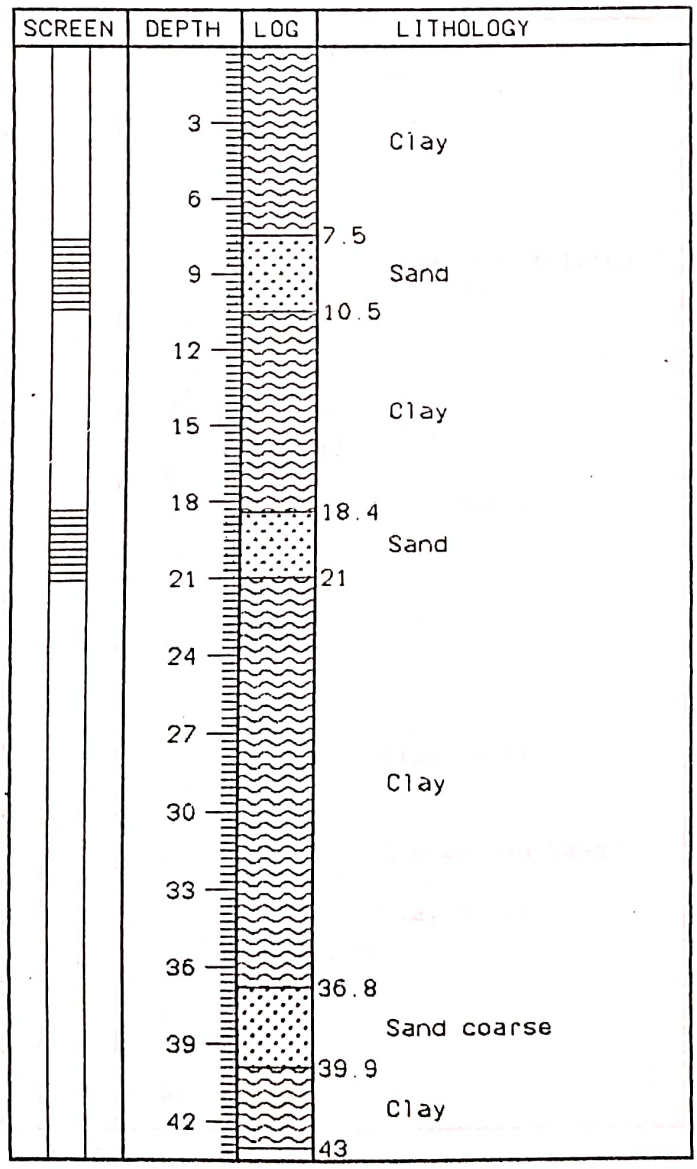
APPENDIX 3/25

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. UN 26	Location: PADARIYA
Elevation: 95.1	X = 724250 Y = 3040000
Method of Drilling:	MANUAL
Drilling Dates :	03.07.89 - 09.07.89
Total Depth :	43.00
Comments :	M.P: 0.30 m. Screen Position: 7.62 - 10.37 m. 18.29 - 21.04 m. Screen Type: Slotted Pipe

W E L L L O G

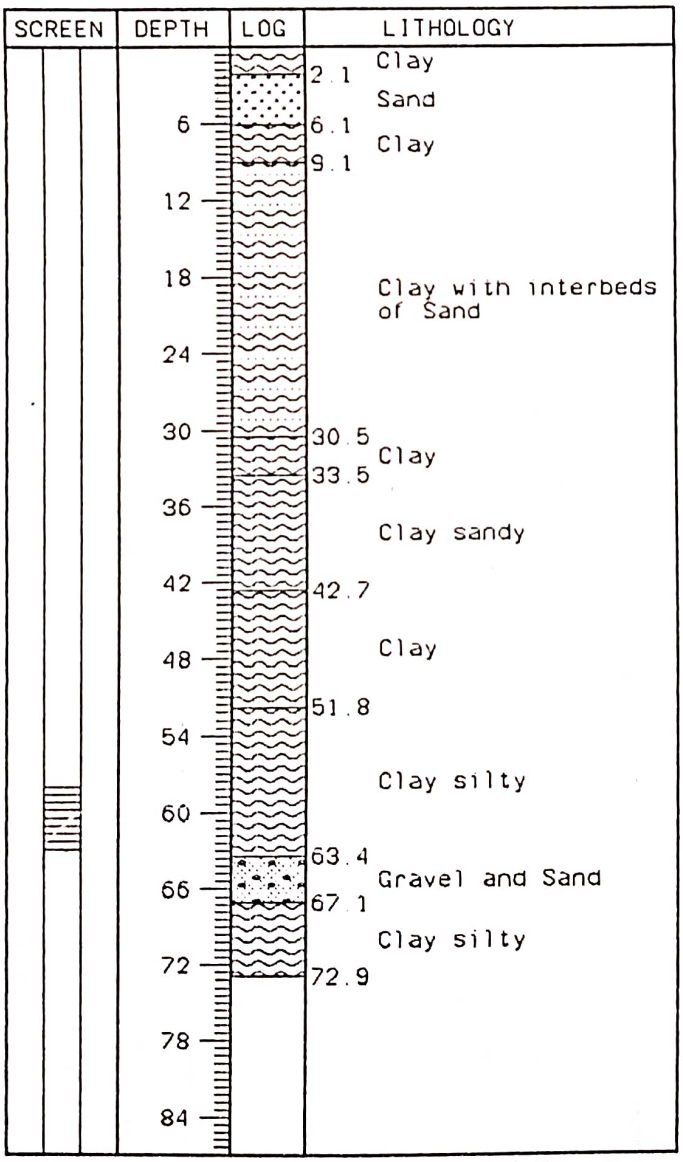


GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. US 4/1	Location: VISHNUPURA
Elevation: 103.6	X = 752750 Y = 3041250
Method of Drilling: RIG	
Drilling Dates : 11.03.71 - 13.03.71	
Total Depth : 72.90	
Comments : Well Size: 1.5" Screen Position: 57.9 - 62.8 m. Drilled Under: GWRDB/USAID	

W E L L L O G



PUMPING TEST

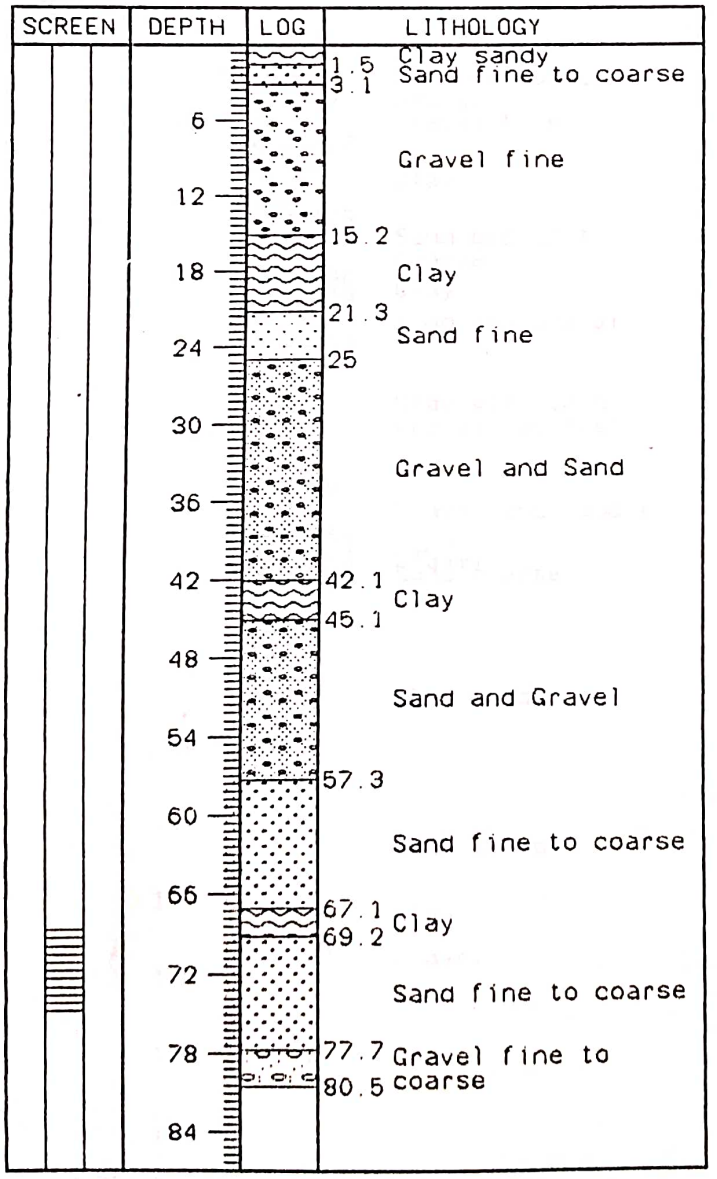
Date: 10.04.72
Capacity: 0.5 l/sec
Duration: 20 hrs.
Transmiss.: 160 m2/day
Method : Recovery
SWL: 1.1 m.(A.GR.L)
DWL: 0.0 m.(GR.L)

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. US 4/4	Location: BELAHIA
Elevation: 113.7	X = 752375 Y = 3048500
Method of Drilling: RIG	
Drilling Dates : 06.03.71 - 15.03.71	
Total Depth : 80.50	
Comments : Well Size: 10"/6" Screen Position: 68.6 - 74.7 m. Drilled Under: GWRDB/USAID	

W E L L L O G



PUMPING TEST

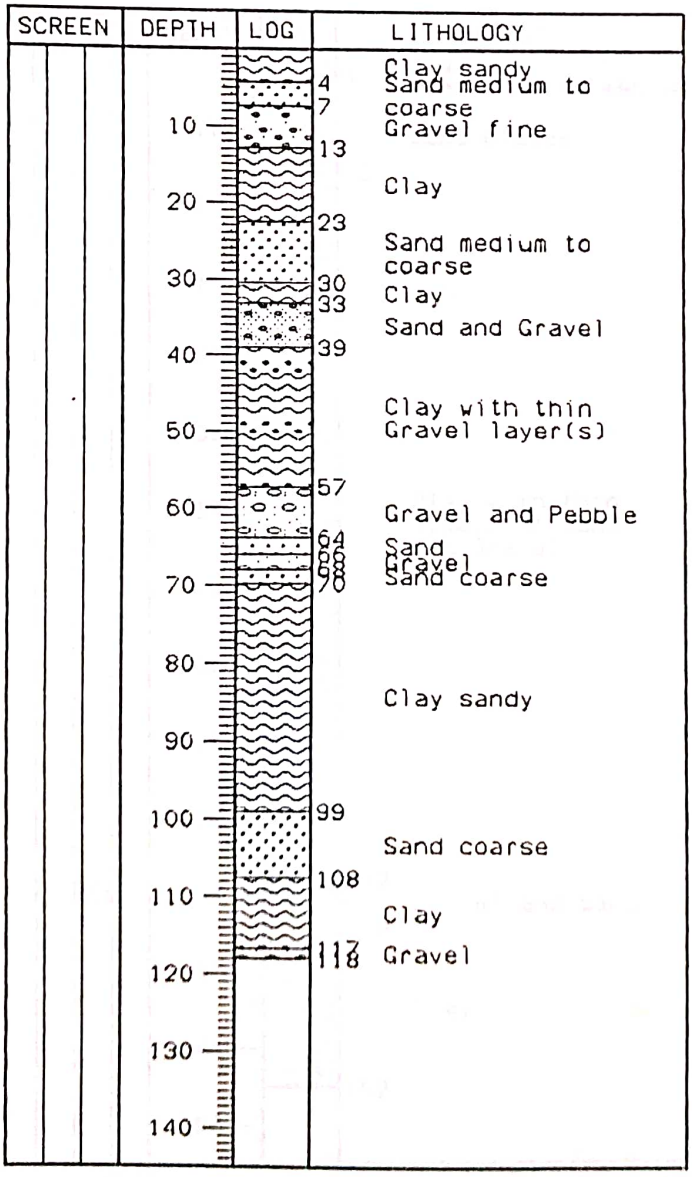
Date: 24.03.72
Capacity: 16.5 l/sec
Duration: 24 hrs.
Transmiss.: 830 m2/day
Method : Theis
Stor.Coeff.: 5.85 E-5
SWL: 9.2 m.(A.GR.L)
DWL: 0.0 m.(GR.L)

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

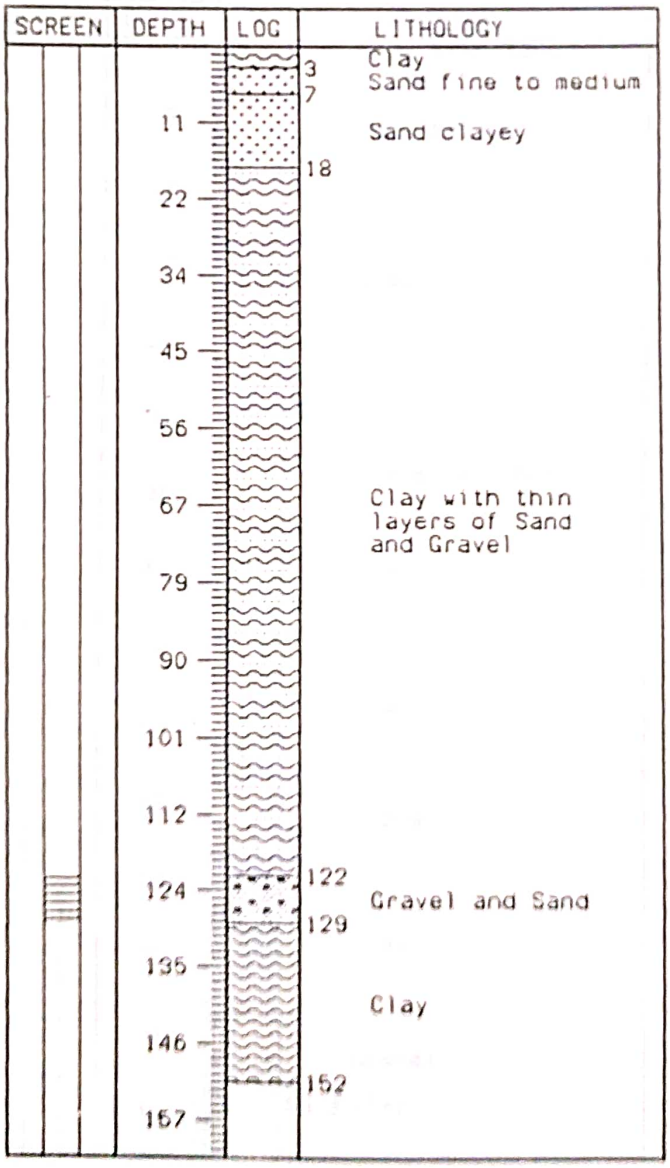
Well No. US 4/5	Location: PETRABANIA
Elevation: 119.8	X = 752000 Y = 3052375
Method of Drilling: RIG	
Drilling Dates : 19.03.71 - 01.04.71	
Total Depth : 118.00	
Comments : Abandoned Drilled Hole Drilled Under: GWRDB/USAID	

W E L L L O G



Well No US 4/6	Location KERWANI
Elevation 134.7	X = 755875 Y = 3059250
Method of Drilling	RIG
Drilling Dates	05.04.71 - 12.04.71
Total Depth	152.00
Comments	Well Size: 8"/4" Screen Position: 121.9 - 128.0 Drilled Under: GWRDB/USAID

W E L L L O G



PUMPING TEST

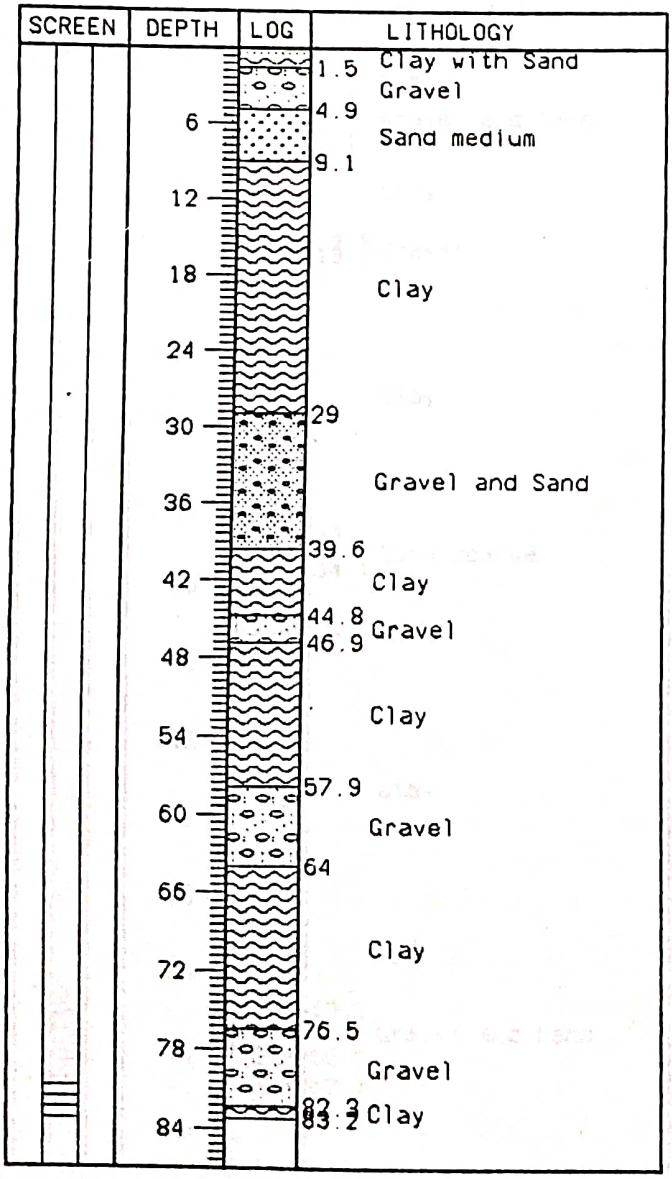
Date	25.03.72
Capacity	2.5 l/sec
Duration	24 hrs.
Transmiss	400 m2/day
Method	Recovery
SWL	7.6 m.(B.GR.L)
DWL	8.7 m.(B.GR.L)

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. US 5/2	Location: PAKLIHAWA
Elevation: 104.3	X = 738375 Y = 3042500
Method of Drilling: RIG	
Drilling Dates : 01.06.71 - 05.06.71	
Total Depth : 83.20	
Comments : Well Size: 6"/4" Screen Position: 80.8 - 83.2 m. Drilled Under: GWRDB/USAID	

W E L L L O G



PUMPING TEST

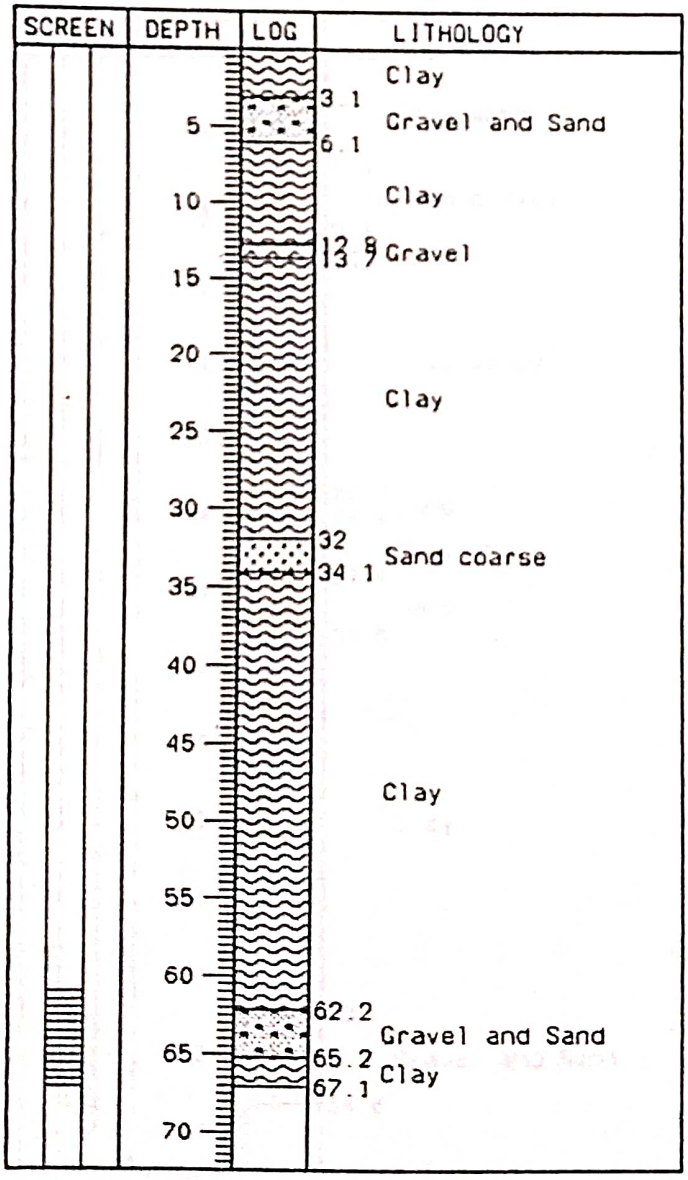
Date: 02.07.72
Capacity: 3.2 l/sec
Duration: 48 hrs.
Transmiss.: 45 m2/day
Method : Recovery
SWL: 10.7 m.(B.GR.L)
DWL: 0.0 m.(GR.L)

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No US 5/7	Location BWA WATER TANK
Elevation 109.7	X = 741125 Y = 3043875
Metnod of Drilling RIG	
Drilling Dates 07.11.71 - 11.11.71	
Total Depth 67.10	
Comments Well Size: 10"/8" Screen Position: 61 - 67.1 m. Drilled Under: GWRDB/USAID	

W E L L L O G



PUMPING TEST

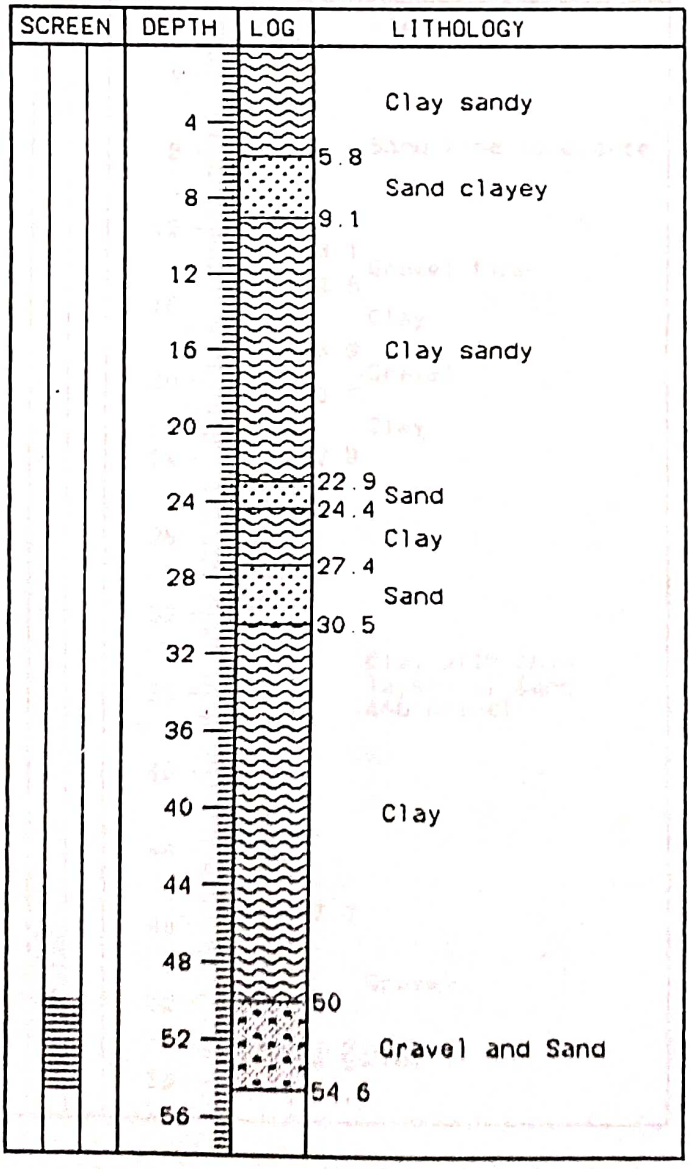
Capacity: 8 l/sec
SWL: 9.4 m.(A.GR.L)

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No US 5/9	Location: AGR. RES. FARM
Elevation: 111.3	X = 742000 Y = 3046500
Method of Drilling: RIG	
Drilling Dates : 02.05.70 - 08.05.70	
Total Depth : 54.60	
Comments : Well Size: 8" Screen Position: 50.0 - 54.6 m. Drilled Under: GWRDB/USAID	

W E L L L O G

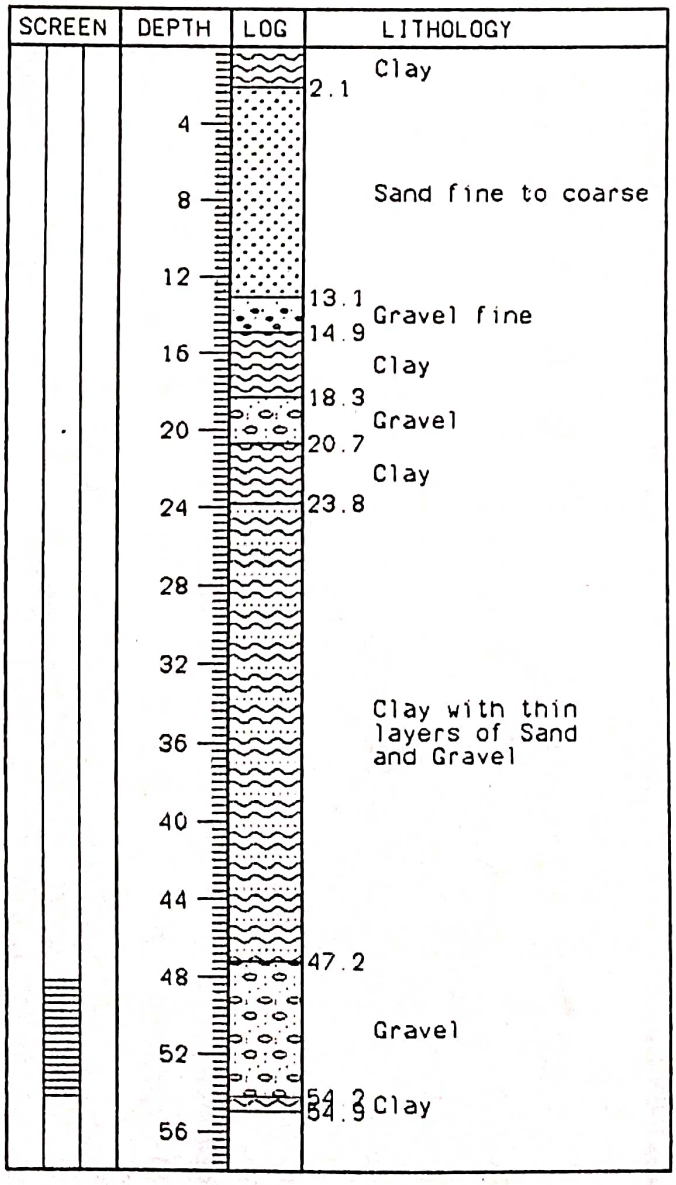


PUMPING TEST

Date: 29.06.72
Capacity: 26.6 l/sec
Duration: 48 hrs.
Transmiss.: 2945 m2/day
Method : Recovery
SWL: 9.2 m.(A.GR.L)
DWL: 0.0 m.(GR.L)

Well No. US 5/10	Location: GOVT. FISH FARM
Elevation: 115.8	X = 742625 Y = 3048500
Method of Drilling: RIG	
Drilling Dates : 15.05.70 - 26.05.72	
Total Depth : 54.90	
Comments : Well Size: 6" Screen Position: 48.2 - 54.3 m. Drilled Under: GWRDB/USAID	

W E L L L O G



PUMPING TEST

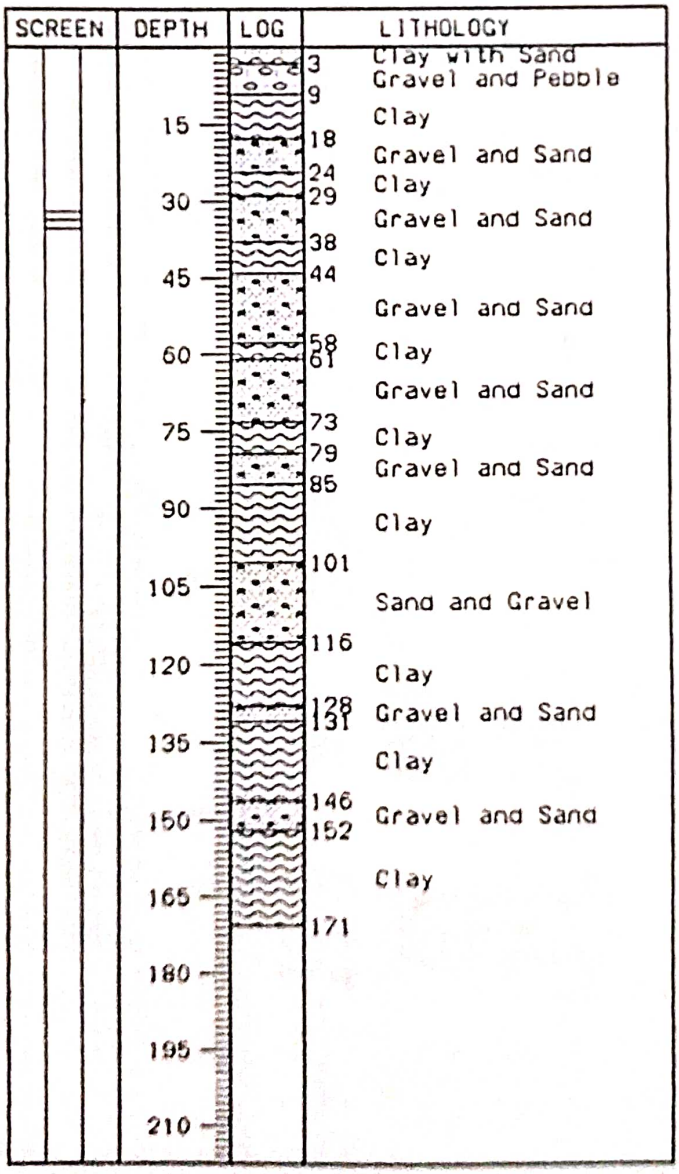
Date: 15.03.72
Capacity: 31 l/sec
Duration: 24 hrs.
Transmiss.: 2155 m2/day
Method : Theis
Stor.Coeff.: 1.1 E-4
SWL: 9.7 m.(A.GR.L)
DWL: 0.0 m.(GR.L)

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. US 5/13	Location: MANGLAPUR
Elevation: 121.9	X = 743250 Y = 3053375
Method of Drilling: RIG	
Drilling Dates: 16.06.71 - 21.06.71	
Total Depth: 170.70	
Comments: Well Size: 1.5" Screen Position: 32 - 35.1 m. Drilled Under: GWRDB/USAID	

W E L L L O G



PUMPING TEST

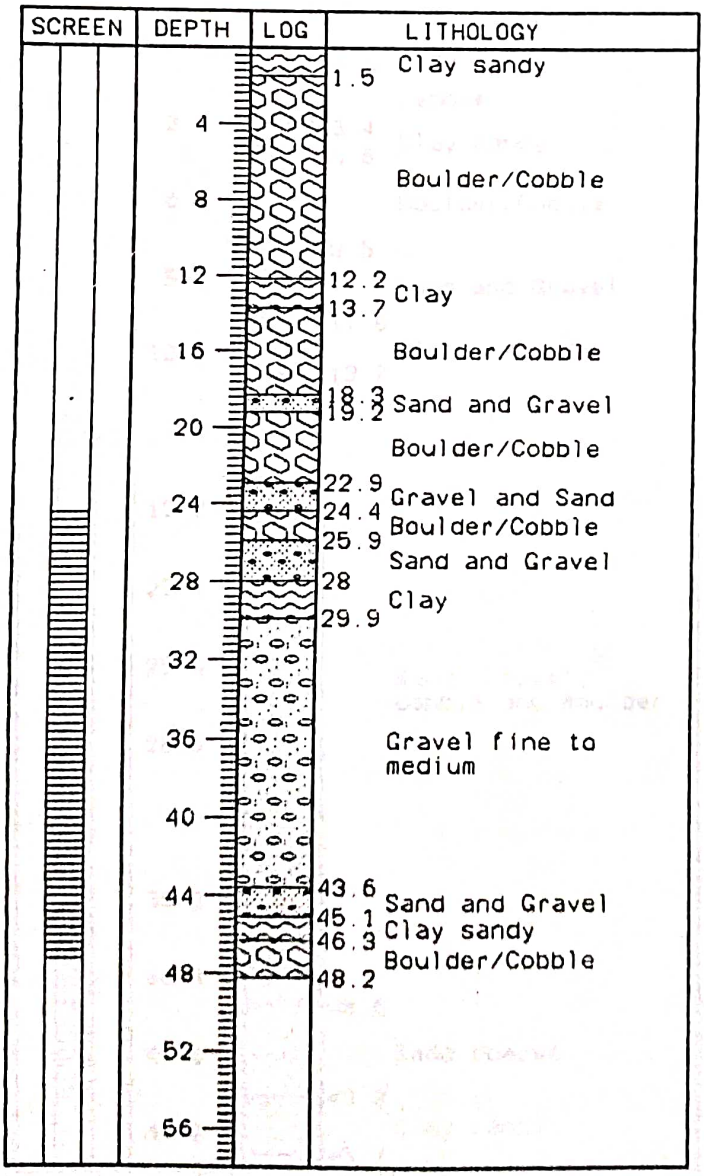
Capacity: 1 l/s (flowing)
SWL: 3.1 m.(A.GR.L)

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. US 5/14	Location: MANIGRAM
Elevation: 128.6	X = 743125 Y = 3056625
Method of Drilling: RIG	
Drilling Dates : 10.06.69 - 10.06.69	
Total Depth : 48.20	
Comments : Well Size: 14"/8" Sceen Position: 24.4 - 47.2 m. Drilled Under: GWRDB/USAID	

W E L L L O G



PUMPING TEST

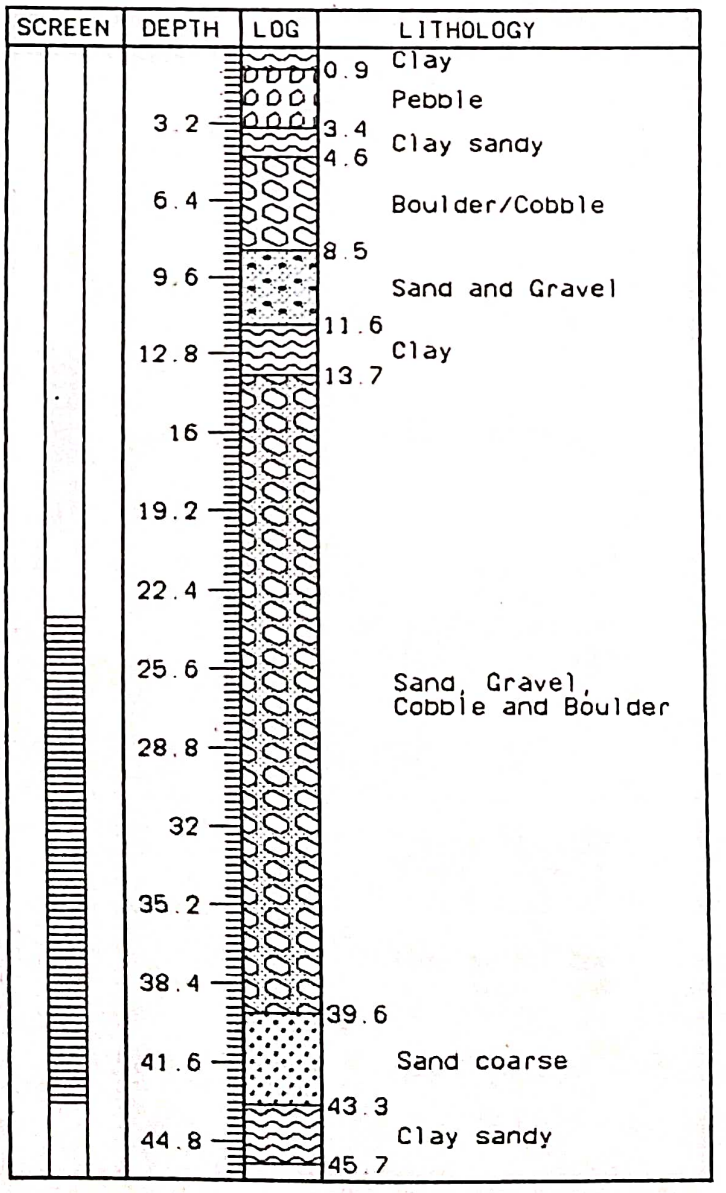
Date: 07.03.72
Capacity: 76.6 l/sec
Duration: 48 hrs.
Transmiss.: 16465 m2/day
Method : Theis
Stor.Coeff.: 2.79 E-4
SWL: 3.4 m.(B.GR.L)
DWL: 5.2 m.(B.GR.L)

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. US 5/18	Location: JOGIKUTI
Elevation: 153.9	X = 742875 Y = 3061875
Method of Drilling: RIG	
Drilling Dates : 28.01.71 - 29.04.71	
Total Depth : 45.70	
Comments : Well Size: 10"/8" Screen Position: 23.5 - 43.3 m. Drilled Under: GWRDB/USAID	

W E L L L O G



PUMPING TEST

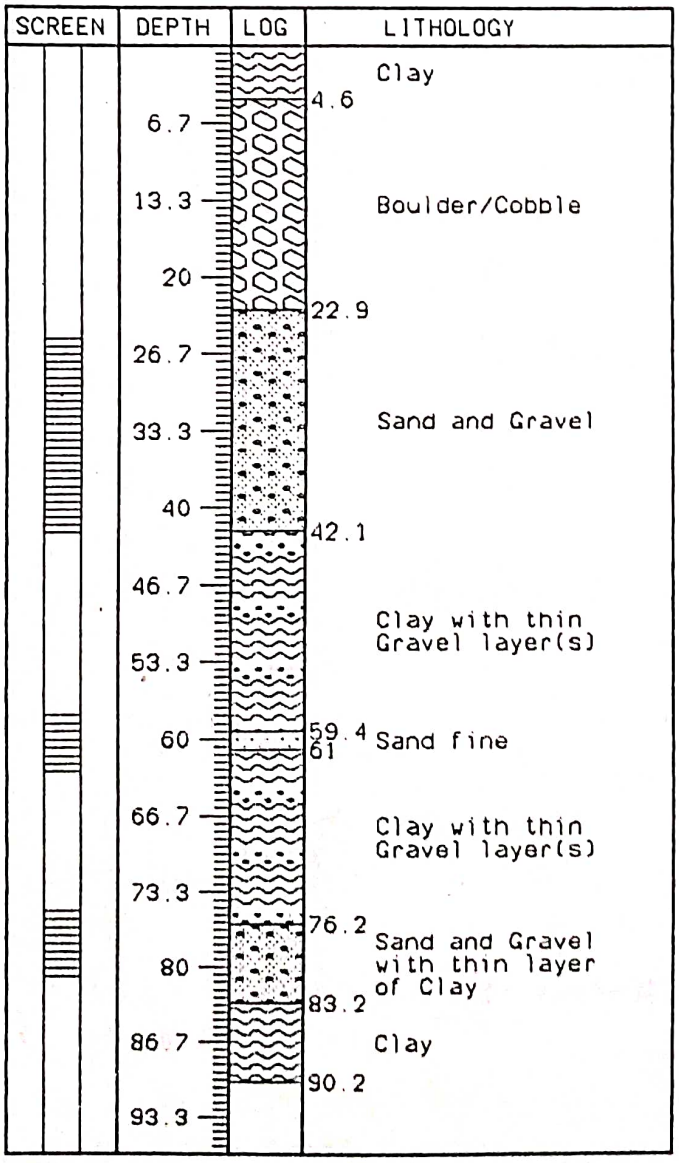
Date: 10.02.72
Capacity: 25 l/sec
Duration: 24 hrs.
Transmiss.: 5430 m2/day
Method : Recovery
SWL: 12.5 m.(B.GR.L)
DWL: 13.8 m.(B.GR.L)

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. US 5/19	Location: BUTWAL
Elevation: 174	X = 743375 Y = 3064000
Method of Drilling: RIG	
Drilling Dates : 19.05.71 - 22.09.71	
Total Depth : 90.20	
Comments : Well Size: 14"/8" Screen Position: 25.3 - 42.1 m. 57.9 - 62.8 m. 75.0 - 80.8 m. Drilled Under: GWRDB/USAID	

W E L L L O G



PUMPING TEST

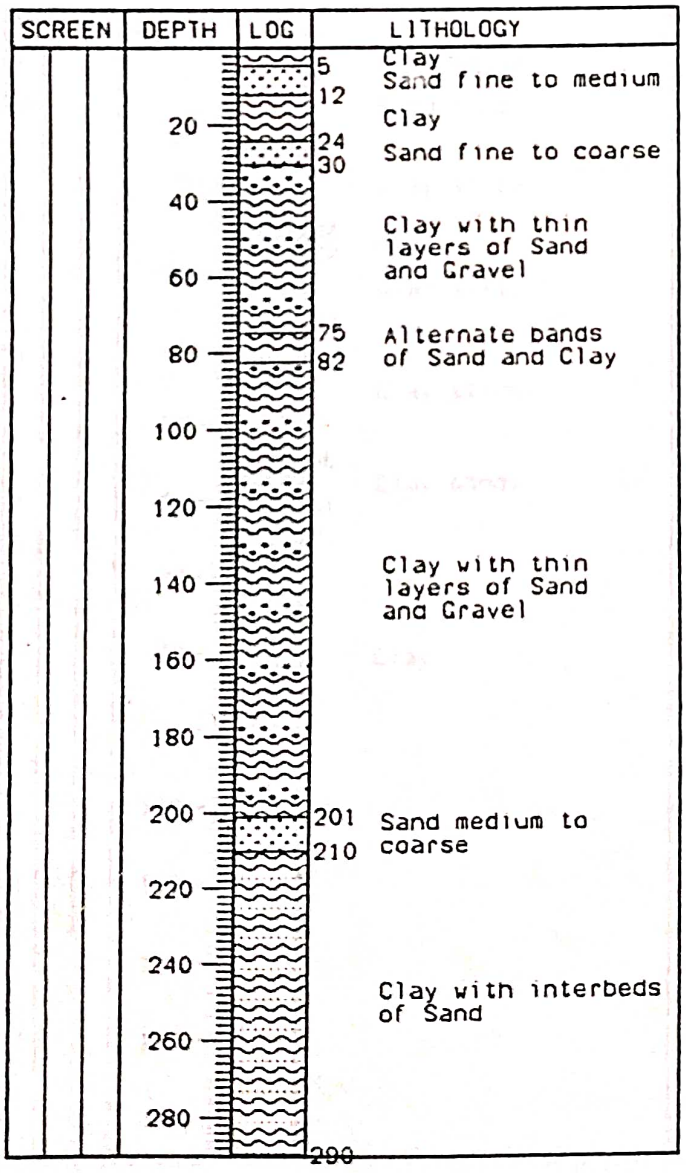
Date: 15.01.72
Capacity: 21.2 l/sec
Duration: 24 hrs.
Transmiss.: 2345 m2/day
Method : Recovery
SWL: 12.8 m.(B.GR.L)
DWL: 16.0 m.(B.GR.L)

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

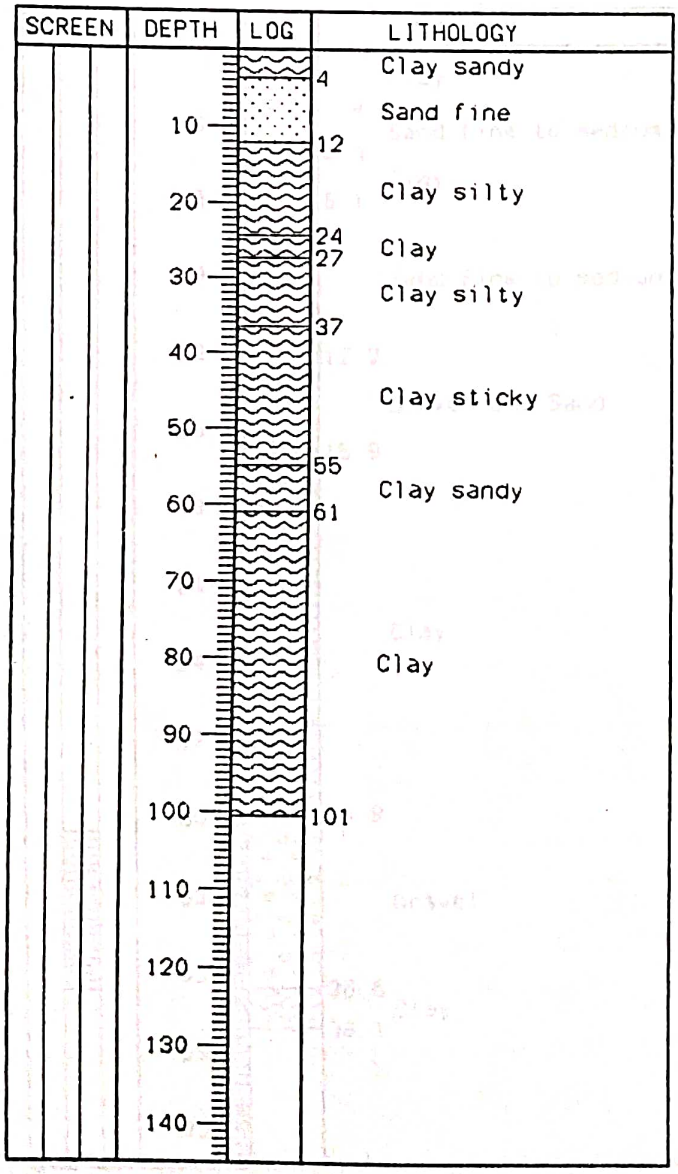
Well No. US 6/1	Location: JIGNA
Elevation: 93	X = 727250 Y = 3029375
Method of Drilling: RIG	
Drilling Dates : 25.01.71 - 31.01.71	
Total Depth : 289.60	
Comments : Abandoned Drilled Hole Drilled Under: GWRDB/USAID	

W E L L L O G



Well No. US 6/2	Location: SONBARSA
Elevation: 89.3	X = 730500 Y = 3026500
Method of Drilling: RIG	
Drilling Dates : 10.02.72 - 10.02.72	
Total Depth : 100.60	
Comments : Abandoned Drilled Hole Drilled Under: GWRDB/USAID	

W E L L L O G

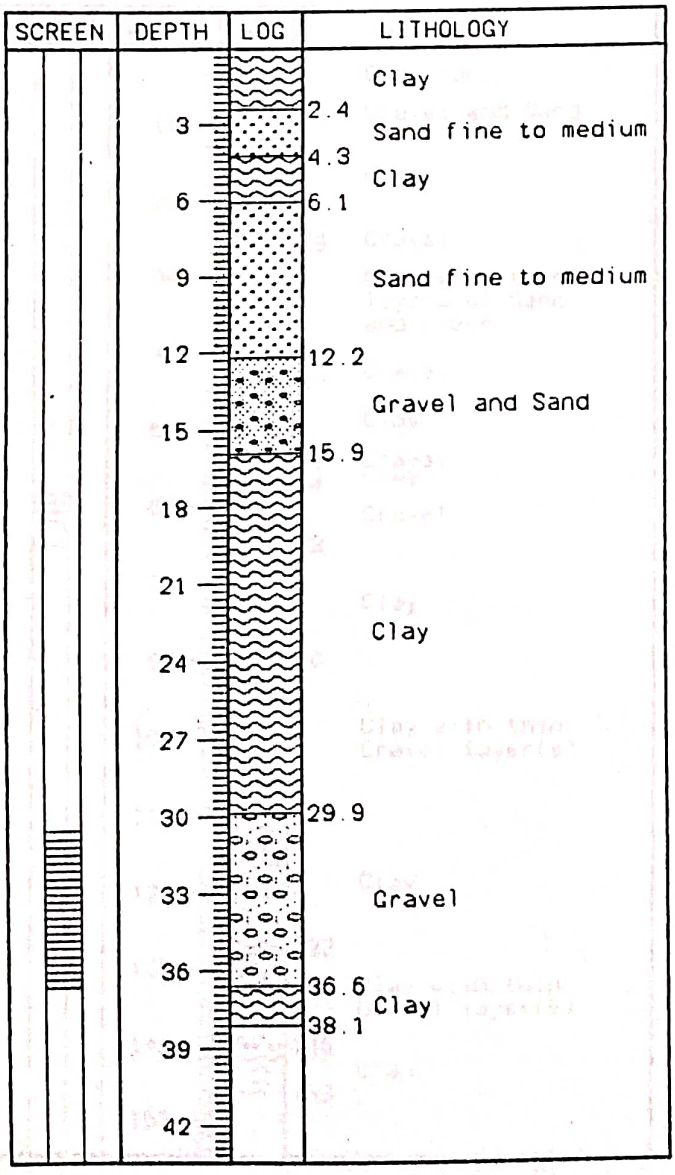


GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. US 6/4	Location: BOGRI
Elevation: 96.9	X = 736375 Y = 3032750
Method of Drilling: RIG	
Drilling Dates : 17.02.72 - 18.02.72	
Total Depth : 38.10	
Comments : Well Size: 8" Screen Position: 30.5 - 36.6 m. Drilled Under: GWRDB/USAID	

W E L L L O G



PUMPING TEST

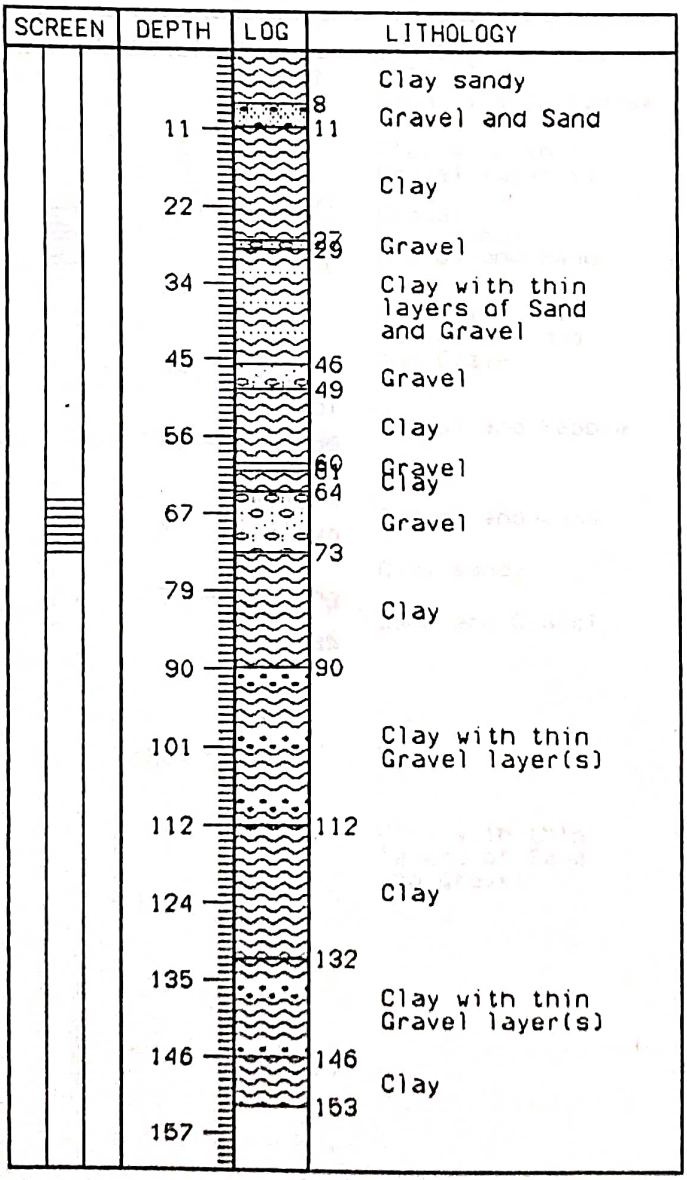
Date: 30.04.72
Capacity: 3.2 l/sec
Duration: 48 hrs.
Transmiss.: 180 m2/day
Method : Theis
Stor.Coeff.: 2.16 E-4
SWL: 3.0 m.(B.GR.L)
DWL: 5.1 m.(B.GR.L)

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. US 6/7	Location: SEMRI
Elevation: 100.6	X = 731500 Y = 3041750
Method of Drilling:	RIG
Drilling Dates :	29.05.72 - 31.05.72
Total Depth :	153.30
Comments :	Well Size: 4" Screen Position: 65.5 - 73.2 m. Drilled Under: GWRDB/USAID

W E L L L O G



PUMPING TEST

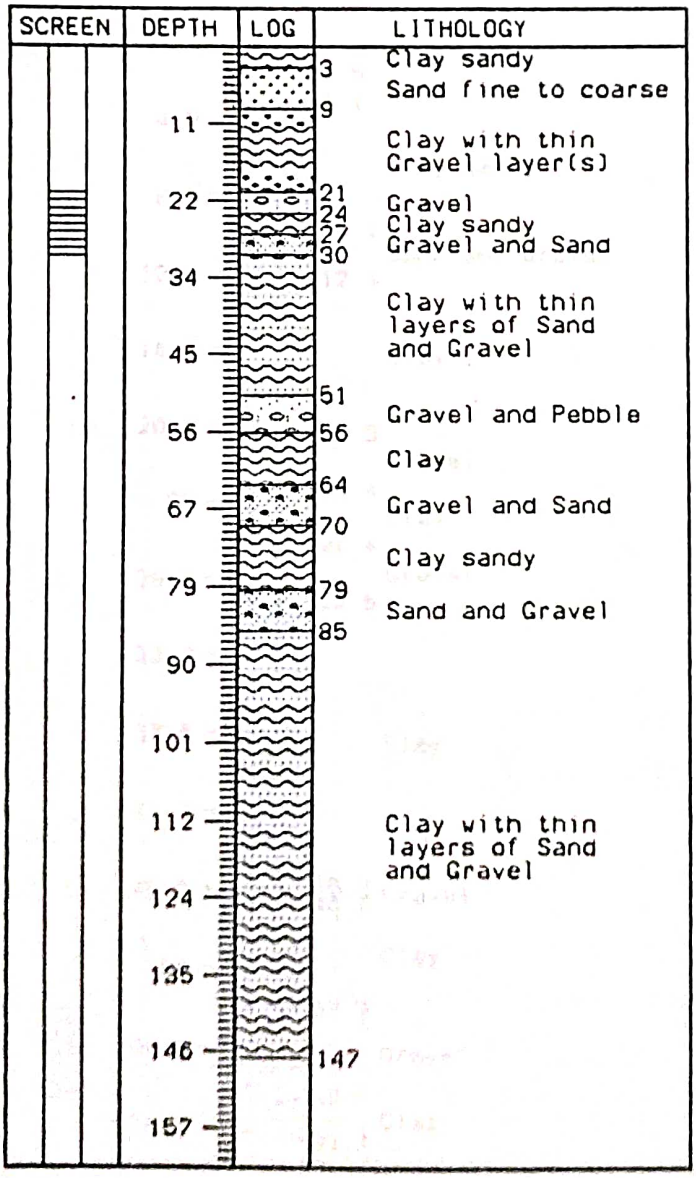
Date: 09.06.72
Capacity: 5 l/sec
Duration: 24 hrs.
Transmiss.: 1035 m2/day
Method : Recovery
SWL: 13.3 m.(A.GR.L)
DWL: 0.0 m.(GR.L)

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. US 6/8	Location: CHILIA
Elevation: 109.7	X = 732625 Y = 3047250
Method of Drilling: RIG	
Drilling Dates: 09.12.71 - 16.12.71	
Total Depth: 147.20	
Comments: Well Size: 8" Screen Position: 21.3 - 30.5 m. Drilled Under: GWRDB/USAID	

W E L L L O G



PUMPING TEST

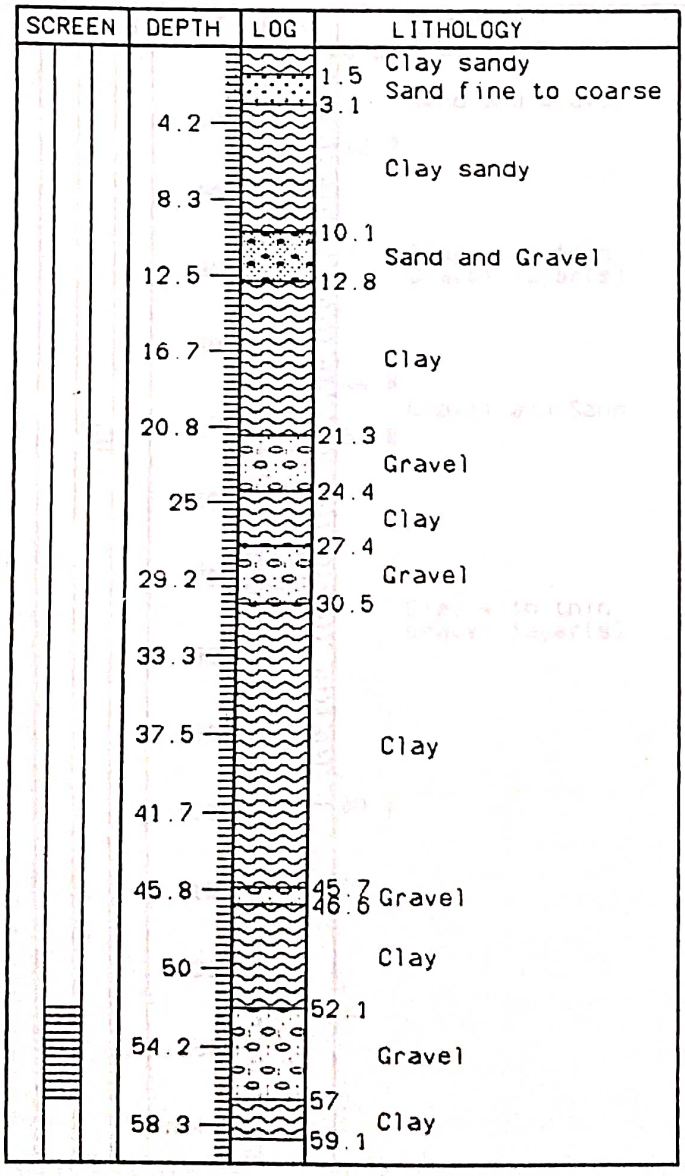
Date	06.05.72
Capacity	3.2 l/sec
Duration	60 hrs.
Transmiss	395 m2/day
Method	Theis
Stor.Coeff.	1.65 E-4
SWL	0.2 m.(A.GR.L)
DWL	1.1 m.(B.GR.L)

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. US 6/10	Location: BAIDAULI
Elevation: 112.8	X = 733375 Y = 3048250
Method of Drilling: RIG	
Drilling Dates : 18.12.72 - 21.12.72	
Total Depth : 59.10	
Comments : Well Size: 8" Screen Position: 52.1 - 57 m. Drilled Under: GWRDB/USAID	

W E L L L O G



PUMPING TEST

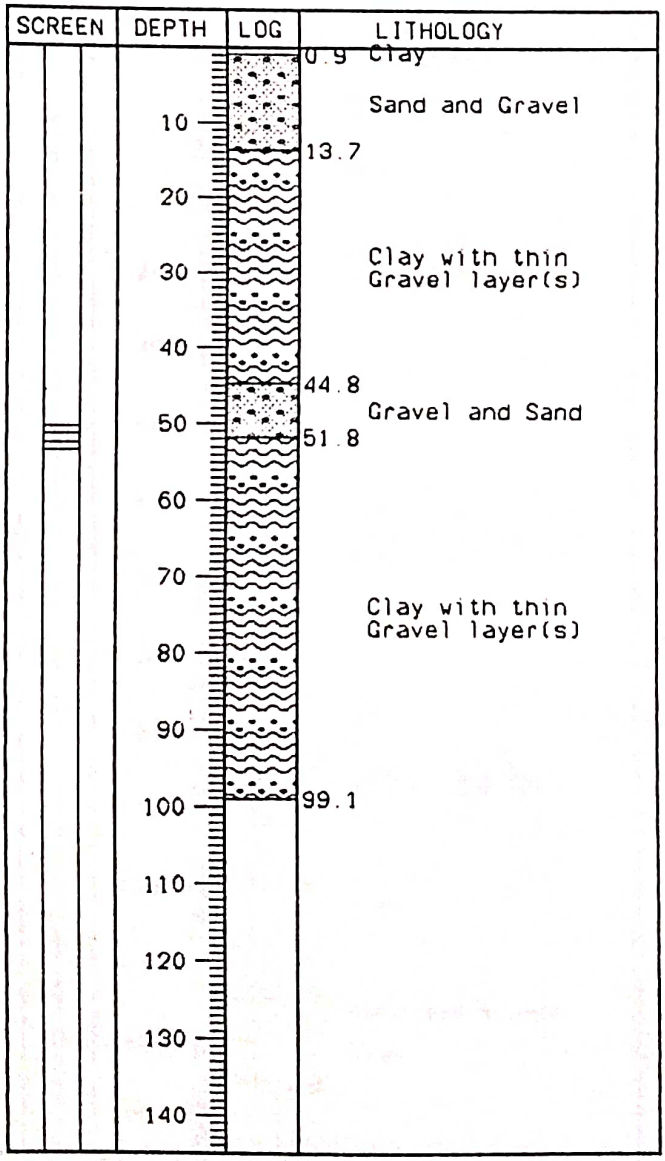
Date:	16.04.72
Capacity:	28.5 l/sec
Duration:	24 hrs.
Transmiss.:	1605 m2/day
Method :	Theis
Stor.Coeff.:	6.2 E-5
SWL:	7.5 m.(A.GR.L)
DWL:	0.0 m.(GR.L)

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. US 6/12	Location: BHUJAULI
Elevation: 121	X = 732375 Y = 3057625
Method of Drilling: RIG	
Drilling Dates : 28.12.71 - 31.12.71	
Total Depth : 99.10	
Comments : Well Size: 3" Screen Position: 50.3 - 53.3 m. Drilled Under: GWRDB/USAID	

W E L L L O G



PUMPING TEST

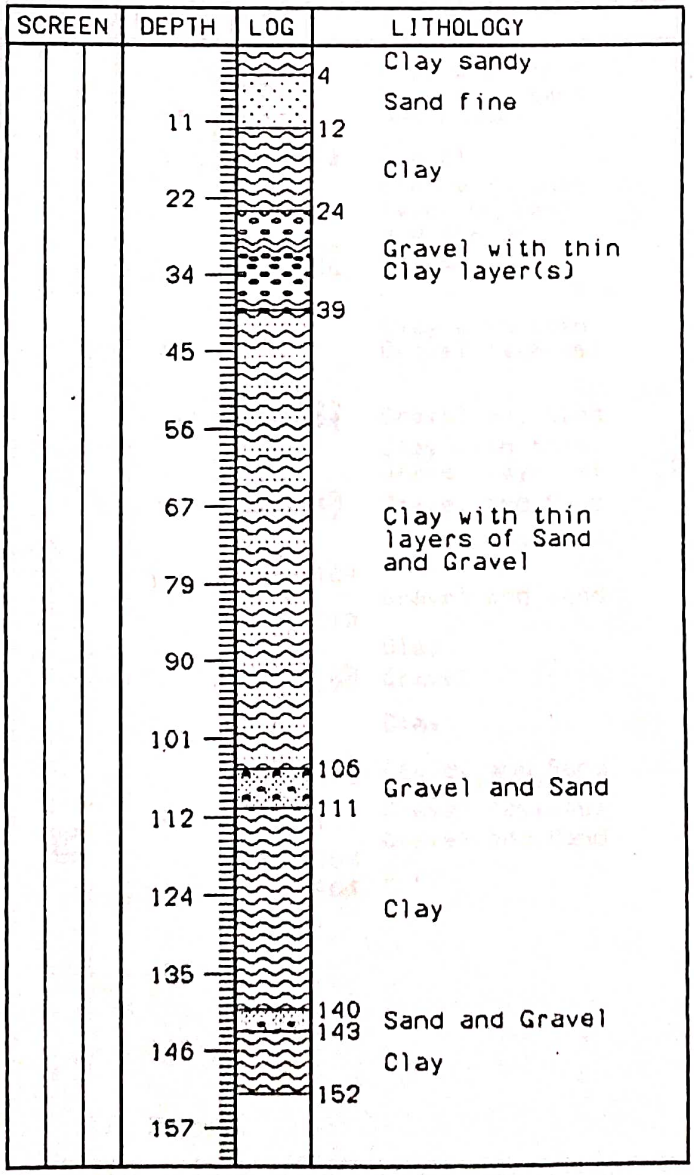
Date: 22.04.72
Capacity: 1.4 l/sec
Duration: 70 hrs.
Transmiss.: 805 m2/day
Method : Recovery
SWL: 4.1 m.(A.GR.L)
DWL: 0.0 m.(GR.L)

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. US 7/1	Location: MAHAJIDIA
Elevation: 98.8	X = 726750 Y = 3039750
Method of Drilling: RIG	
Drilling Dates : 20.02.72 - 22.02.72	
Total Depth : 152.40	
Comments : Abandoned Drilled Hole Drilled Under: GWRDB/USAID	

W E L L L O G

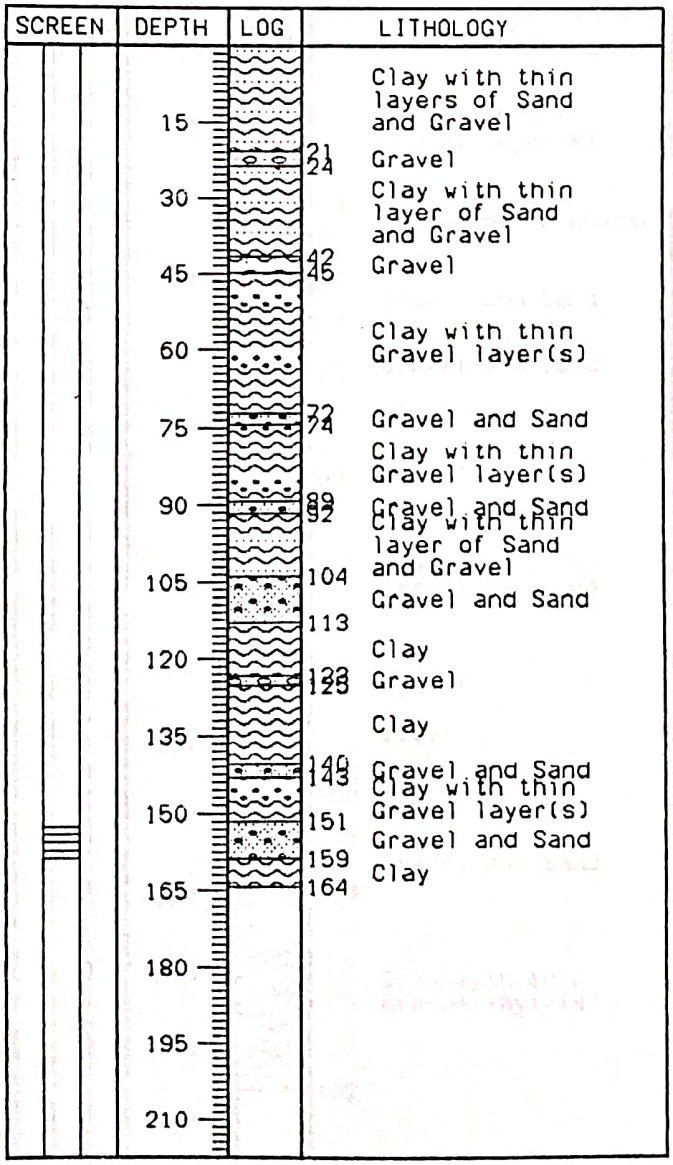


GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. US 8/3	Location: MUGHLA
Elevation: 94.5	X = 720625 Y = 3042125
Method of Drilling:	RIG
Drilling Dates :	17.01.72 - 26.01.72
Total Depth :	164.30
Comments :	Well Size: 6" Screen Position: 152.4 - 158.5 Drilled Under: GWRDB/USAID

W E L L L O G

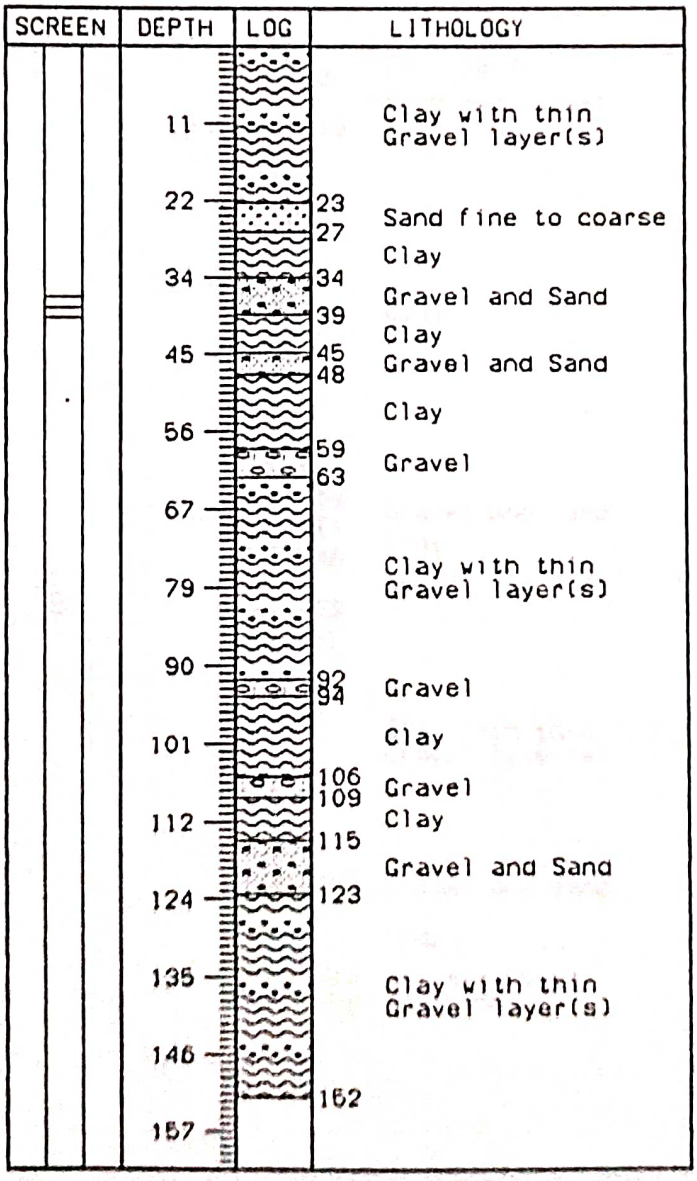


PUMPING TEST

Date:	04.05.72
Capacity:	21.2 l/sec
Duration:	24 hrs.
Transmiss.:	265 m2/day
Method :	Theis
Stor.Coeff.:	3.25 E-4
SWL:	12.0 m.(A.GR.L)
DWL:	0.0 m.(GR.L)

Well No US 8/4	Location SARAHAWA
Elevation 100.6	X = 721625 Y = 3048500
Method of Drilling	RIG
Drilling Dates	19.02.72 - 25.02.72
Total Depth	152.40
Comments	Well Size: 3" Screen Position: 36.6 - 39.6 m. Drilled Under: GWRDB/USAID

W E L L L O G



PUMPING TEST

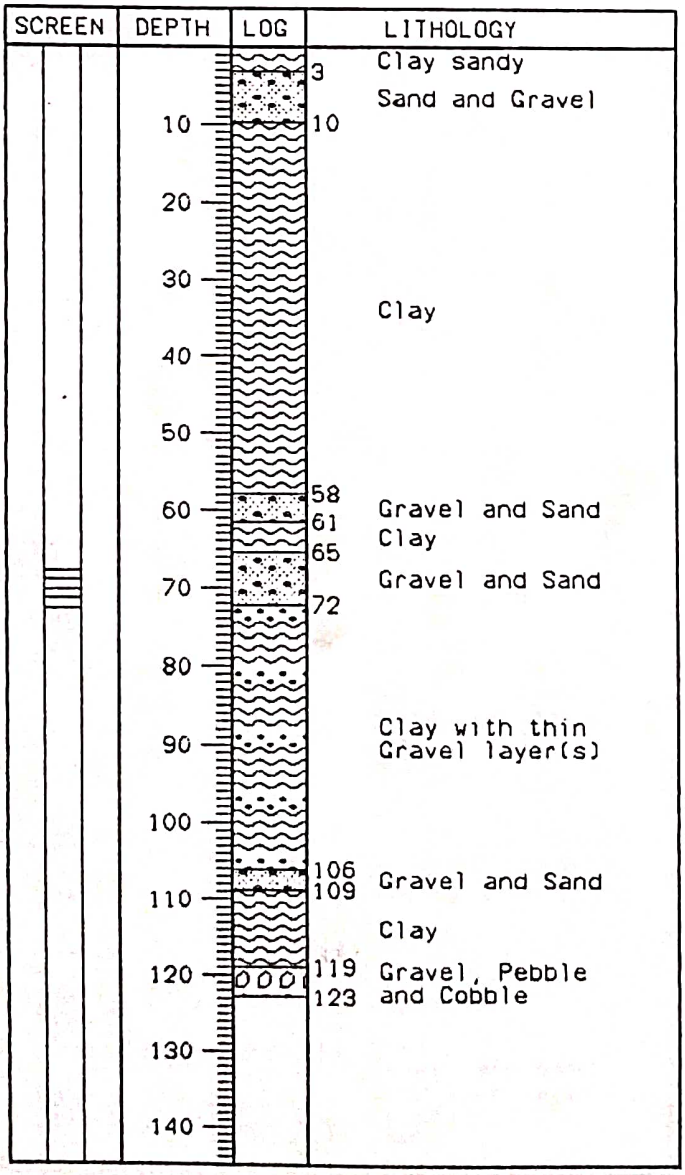
Capacity 0.4 l/s (flowing)
SWL 3.4 m.(A.GR.L)

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. US 8/5	Location: ASNIA
Elevation: 115.8	X = 722125 Y = 3056750
Method of Drilling:	RIG
Drilling Dates :	04.03.72 - 09.03.72
Total Depth :	122.80
Comments :	Well Size: 3" Screen Position: 67.7 - 72.5 m. Drilled Under: GWRDB/USAID

W E L L L O G



PUMPING TEST

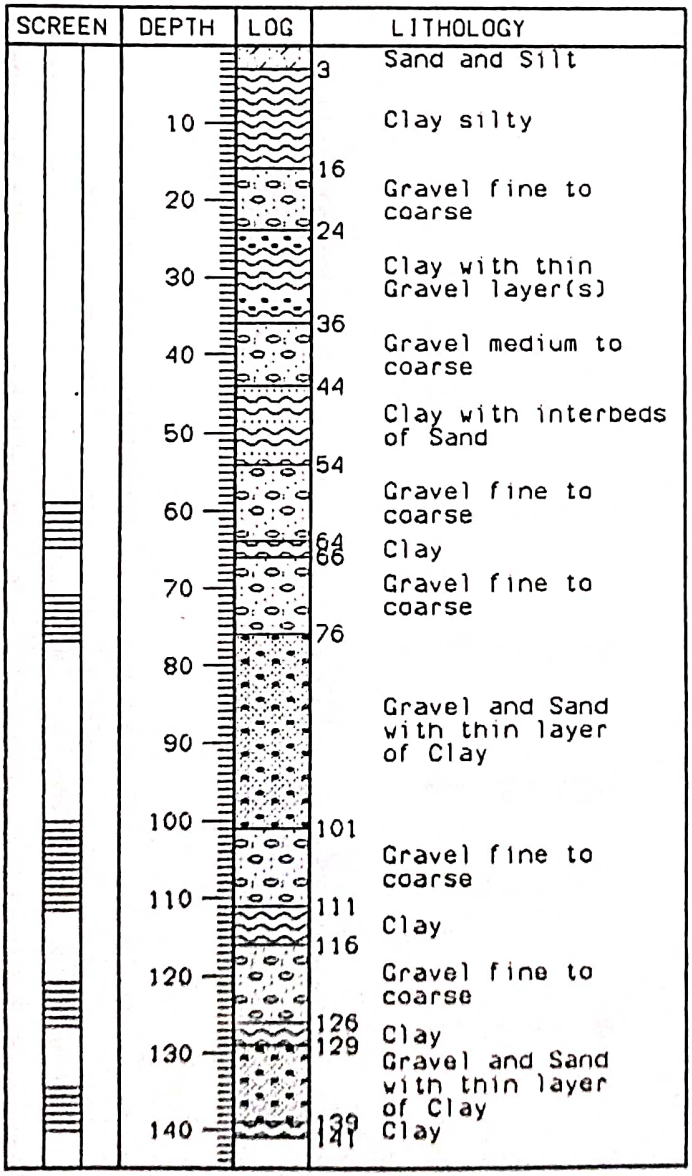
Date: 20.04.72
Capacity: 7.3 l/sec
Duration: 28 hrs.
Transmiss.: 345 m2/day
Method : Recovery
SWL: 11.4 m.(A.GR.L)
DWL: 0.0 m.(GR.L)

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. BL I/19	Location: E. SEMRA
Elevation 123.1	X = 740875 Y = 3055500
Method of Drilling:	RIG
Drilling Dates	29.12.78 - 04.02.79
Total Depth	141.00
Comments :	Well Size: 14"/8"; M.P: 0.20 m Screen Pos: 58.9 - 64.7, 70.8 - 76.8 100.1 - 111.5, 120.8 - 126.5 134.5 - 140.2 Drilled Under: BLGWP

W E L L L O G

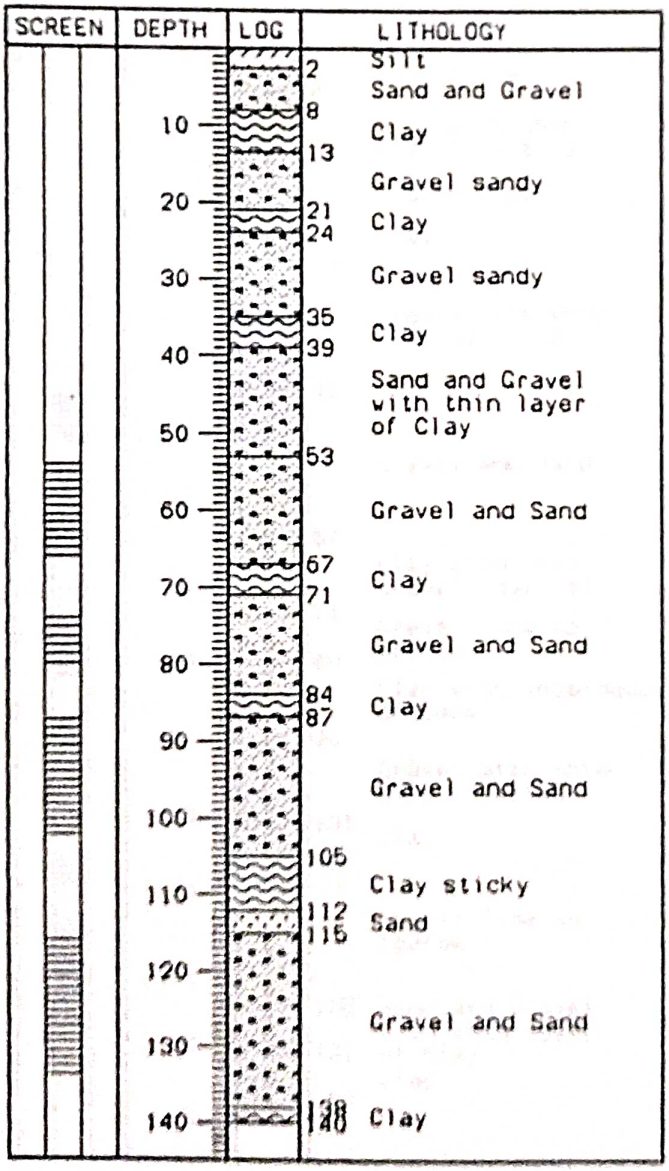


PUMPING TEST

Date:	19 - 20.04.79
Capacity	156 l/sec
Duration:	22 hrs.
Transmiss.:	6500 m2/day
Method :	Theis
Stor.Coeff.:	3.6 E-4
SWL:	4.8 m.(B.GR.L)
DWL:	16.1 m.(B.GR.L)

Well No BL 1/21	Location DUBAULIYA
Elevation 127.6	x = 740250 y = 3058125
Method of Drilling	RIG
Drilling Dates	18.01.79 - 11.03.79
Total Depth	140.00
Comments	Well Size: 14"/8"; M.P: 0.53 m Screen Pos: 53.9 - 65.7, 73.8 - 79.7 87.1 - 95.0, 96.0 - 102.1 115.9 - 133.6 Drilled Under: BLGWP

W E L L L O G



PUMPING TEST

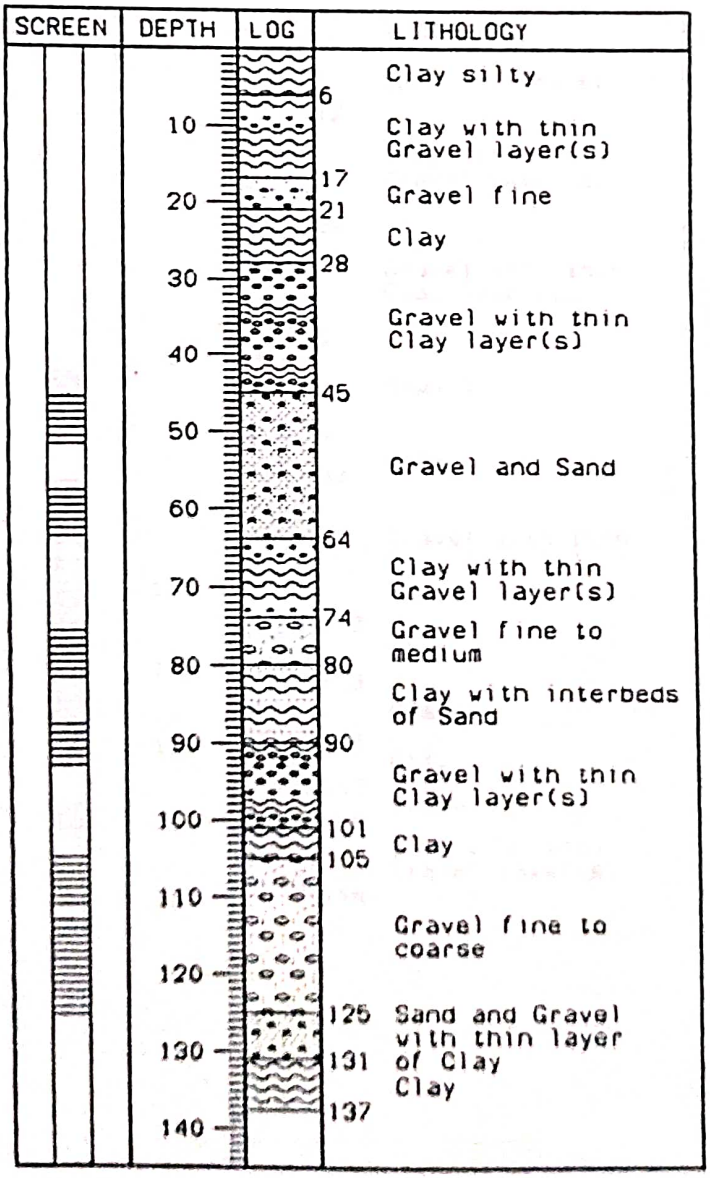
Date	20.03.80
Capacity	107 l/sec
Duration	20 hrs.
Transmiss	6500 m2/day
Method	Jacob
SWL	8.0 m.(B.GR.L)
DWL	16.8 m.(B.GR.L)

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No BL I/27	Location E. KEWALPUR
Elevation 123.9	X = 736750 Y = 3058375
Method of Drilling	RIG
Drilling Dates	01.06.79 - 25.06.79
Total Depth	137.50
Comments	Well Size: 14"/8"; M.P: 0.3 m Screen Pos: 45.4 - 51.5, 57.4 - 63.4 75.5 - 81.5, 87.5 - 92.8 104.8 - 110.9, 113.1 - 125.3 Drilled Under: BLGWP

W E L L L O G

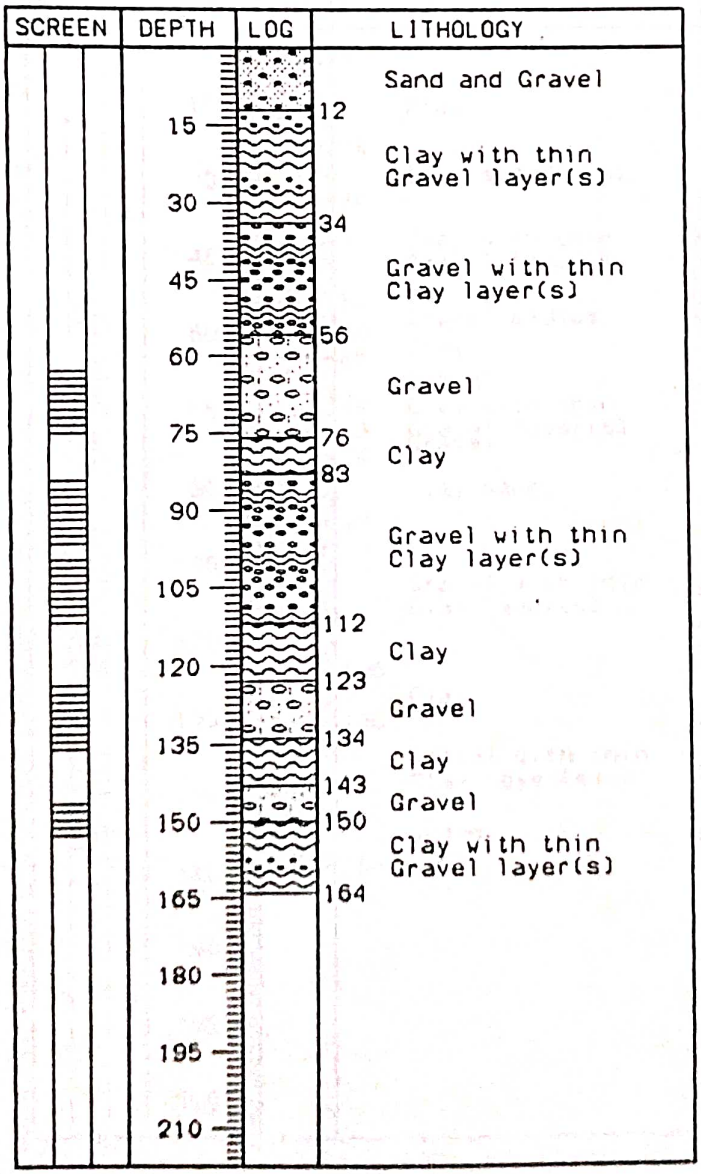


PUMPING TEST

Date	19-20.02.81
Capacity	138 l/sec
Duration	27 hrs.
Transmiss.	15900 m2/day
Method	Theis
Stor.Coeff.	5.4 E-4
SWL	4.31 m.(B.GR.L)
DWL	12.99 m.(B.GR.L)

Well No. BL I/45	Location KANARI
Elevation: 115.5	X = 738125 Y = 3052375
Method of Drilling: RIG	
Drilling Dates: 09.01.81 - 04.02.81	
Total Depth: 164.00	
Comments: Well Size: 16"/8"; M.P: 0.87 m Screen Pos: 62.6 - 74.8, 83.9 - 96.1 99.2 - 111.3, 123.5 - 135.7 146.3 - 152.4 Drilled Under: BLGWP	

W E L L L O G

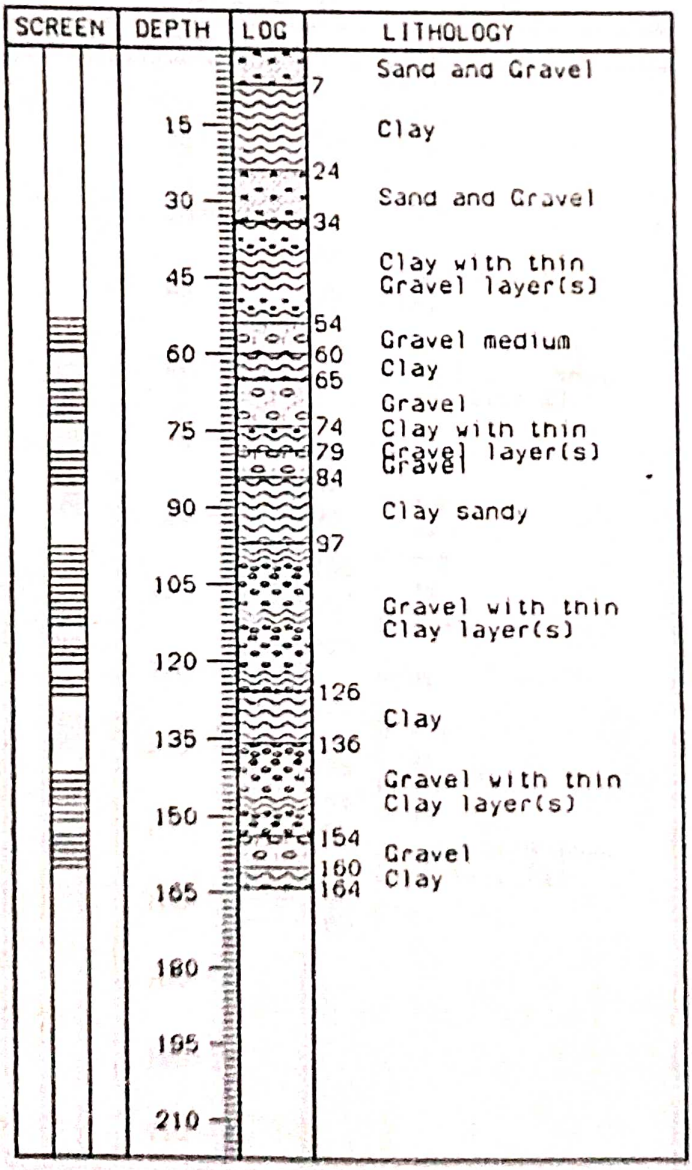


PUMPING TEST

Date: 12-13.02.82
Capacity: 143 l/sec
Duration: 20 hrs.
Transmiss.: 7700 m2/day
Method: Jacob
SWL: 1.9 m.(A.GR.L)
DWL: 14.1 m.(B.GR.L)

Well No BL I/51	Location DAYANAGAR
Elevation 112.8	X = 734000 Y = 3052125
Method of Drilling	RIG
Drilling Dates	02.04.81 - 02.05.81
Total Depth	164.00
Comments	Well Size: 16"/10"; M.P: 1.0 m Scr Pos: 53.3-59.4,65.5-73.2,79.2-85.3 97.5-112.8,117.3-120.4,123.4-126.5 141.7-150.9,153.9-160.0 Drilled Under: BLCWP

WELL LOG



PUMPING TEST

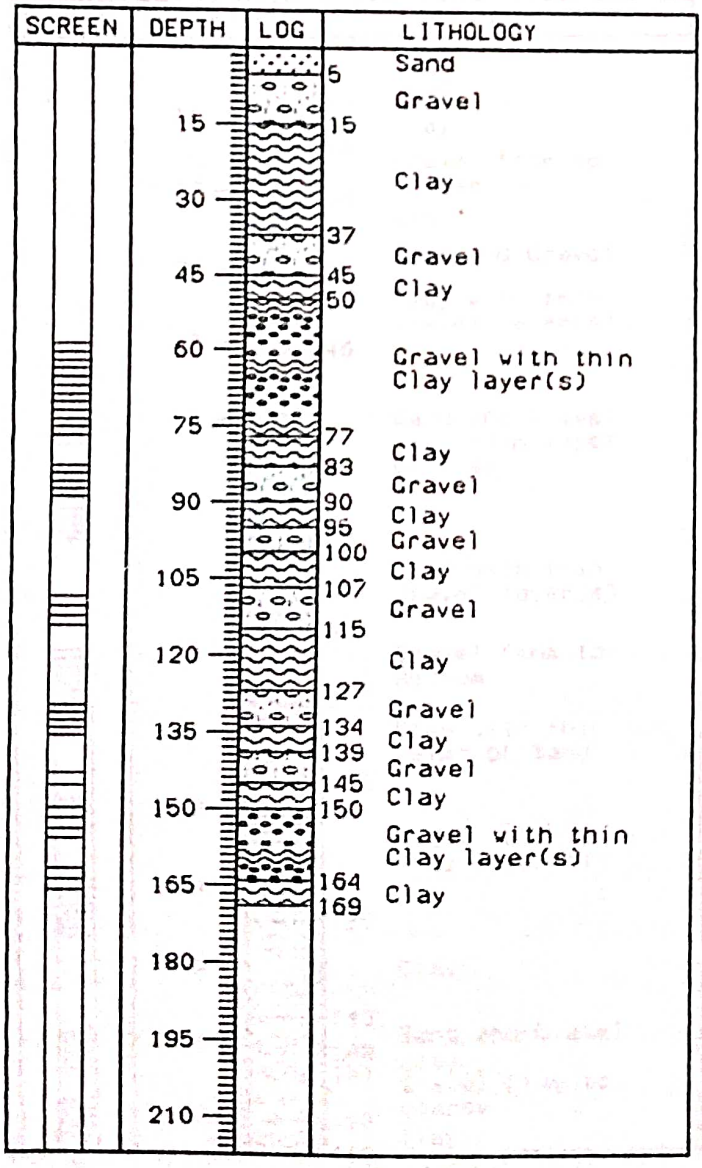
Date	14-15.12.81
Capacity	128 l/sec
Duration	25 hrs.
Transmiss	5200 m2/day
Method	Jacob
SWL	2.5 m.(A.GR.L)
DWL	4.7 m.(B.GR.L)

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. BL I/67	Location: BARAULIYA
Elevation: 116.9	X = 748500 Y = 3052750
Method of Drilling: RIG	
Drilling Dates : 26.12.82 - 02.02.83	
Total Depth : 169.00	
Comments : Well Size: 16"/10"; M.P: 1.47 m Scr Pos: 58.9-76.9,82.8-88.9,108.6-114.3 129.9-136.0,143.4-145.7,150.1-156.0 161.9-166.2 Drilled Under: BLGWP	

W E L L L O G



PUMPING TEST

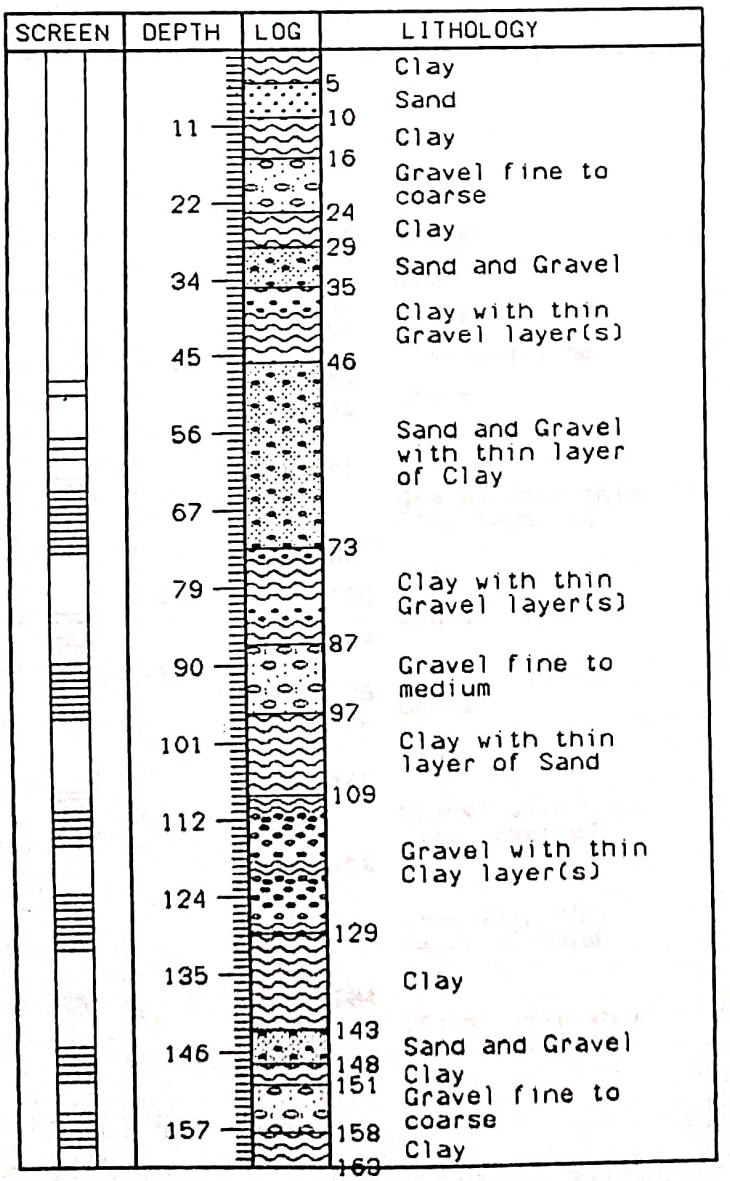
Date: 11.03.83
Capacity: 131 l/sec
Duration: 15 hrs.
Transmiss.: 14000 m2/day
Method: Jacob
SWL: 2.4 m.(A.GR.L)
DWL: 3.6 m.(B.GR.L)

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. BL II/7	Location: N. AHIRAULI
Elevation: 100.7	X = 729250 Y = 3048250
Method of Drilling:	RIG
Drilling Dates :	02.05.86 - 25.05.86
Total Depth :	163.00
Comments :	Well Size: 16"/10"; M.P: 0.19 m Screen Pos: 48.3-50.3,46.5-59.5 64.1-73.2,89.3-97.4,110.9-115.9 123.0-131.1,145.2-150.3,155.0-160.1 Drilled Under: BLGWP

W E L L L O G



PUMPING TEST

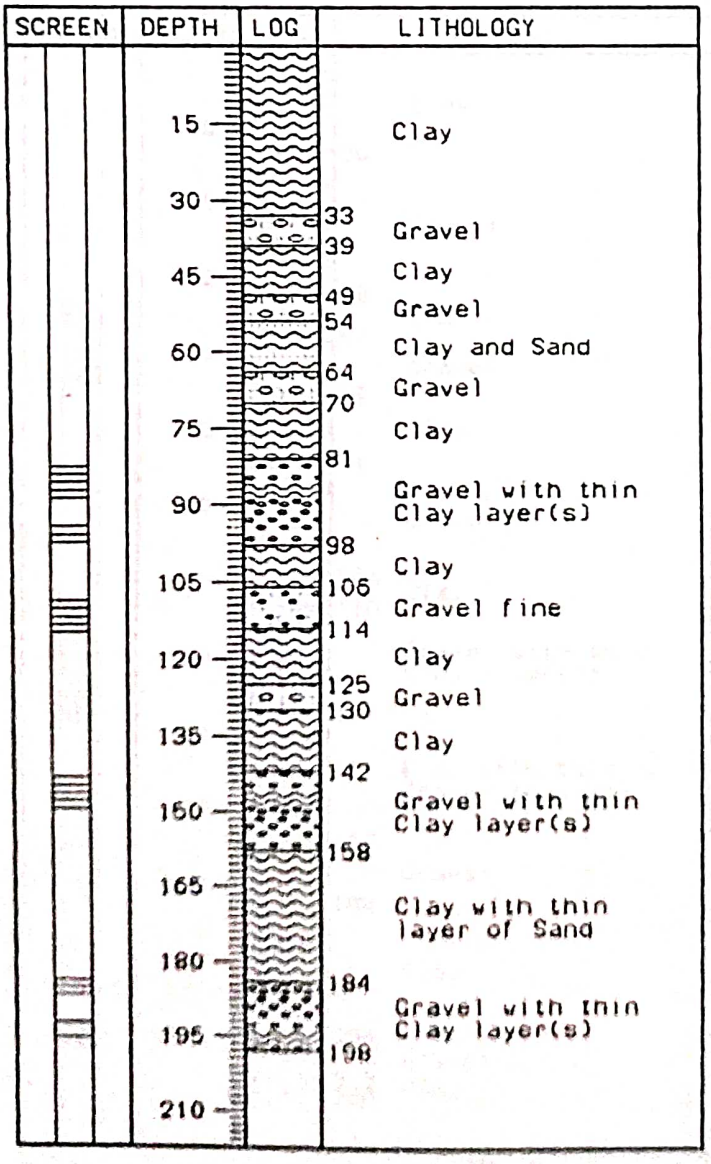
Date: 01-02.02.87
Capacity: 112 l/sec
Duration: 20 hrs.
Transmiss.: 11360 m2/day
Method : Jacob
SWL: 7.66 m.(A.GR.L)
DWL: 9.40 m.(B.GR.L)

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. BL II/12	Location W. BHARAULIA
Elevation 98.5	X = 726375 Y = 3043750
Method of Drilling	RIG
Drilling Dates	16.02.85 - 04.03.85
Total Depth	198.00
Comments	Well Size: 16"/10"; M.P: 0.58 m Screen Pos: 82.3 - 88.5, 94.1 - 97.2 108.4 - 114.6, 143.2 - 149.4 183.7 - 186.8, 192.4 - 195.4 Drilled Under: BLGWP

W E L L L O G



PUMPING TEST

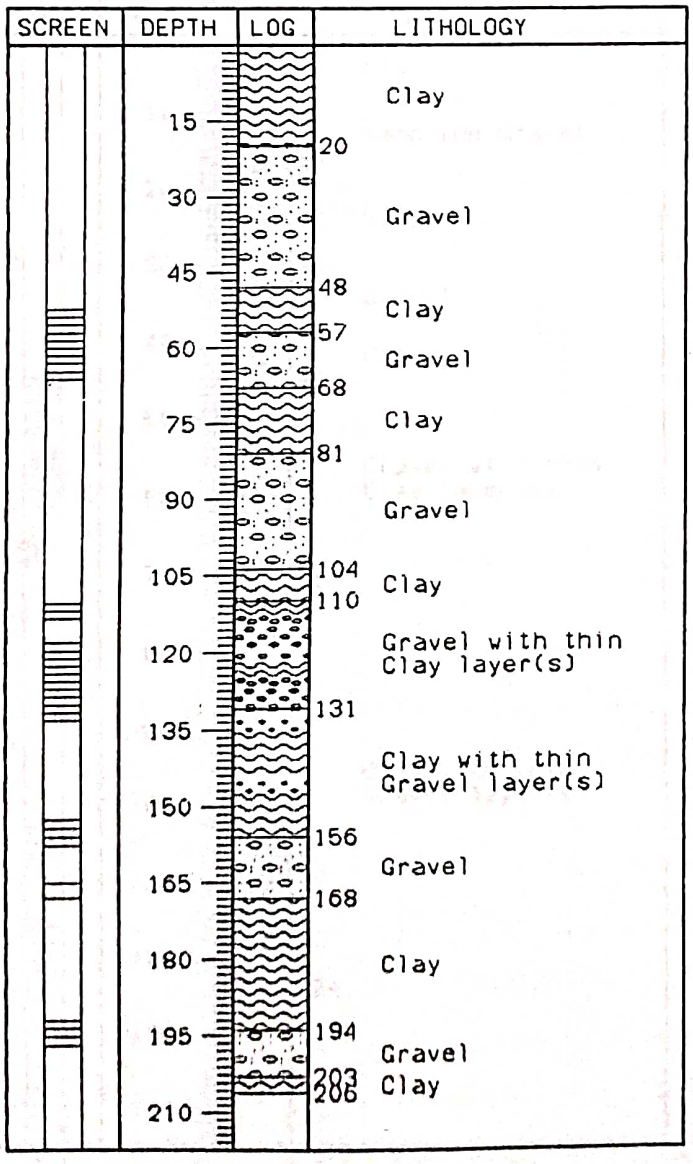
Date	12-13.03.85
Capacity	73.6 l/sec
Duration	20 hrs.
Transmiss.	8620 m2/day
Method	Theis
Stor.Coeff.	5.7 E-6
SWL	6.56 m.(A.GR.L)
DWL	38.8 m.(B.GR.L)

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. BL II/13	Location: SONBARSA
Elevation: 94.2	X = 728375 Y = 3045750
Method of Drilling: RIG	
Drilling Dates : 07.05.85 - 02.06.85	
Total Depth : 206.00	
Comments : Well Size: 16"/10"; M.P: 0.58 m Screen Pos: 52.1 - 65.8, 110.1 - 113.1 117.8 - 132.9, 152.5 - 157.5 164.9 - 167.9, 191.9 - 196.9 Drilled Under: BLGWP	

W E L L L O G

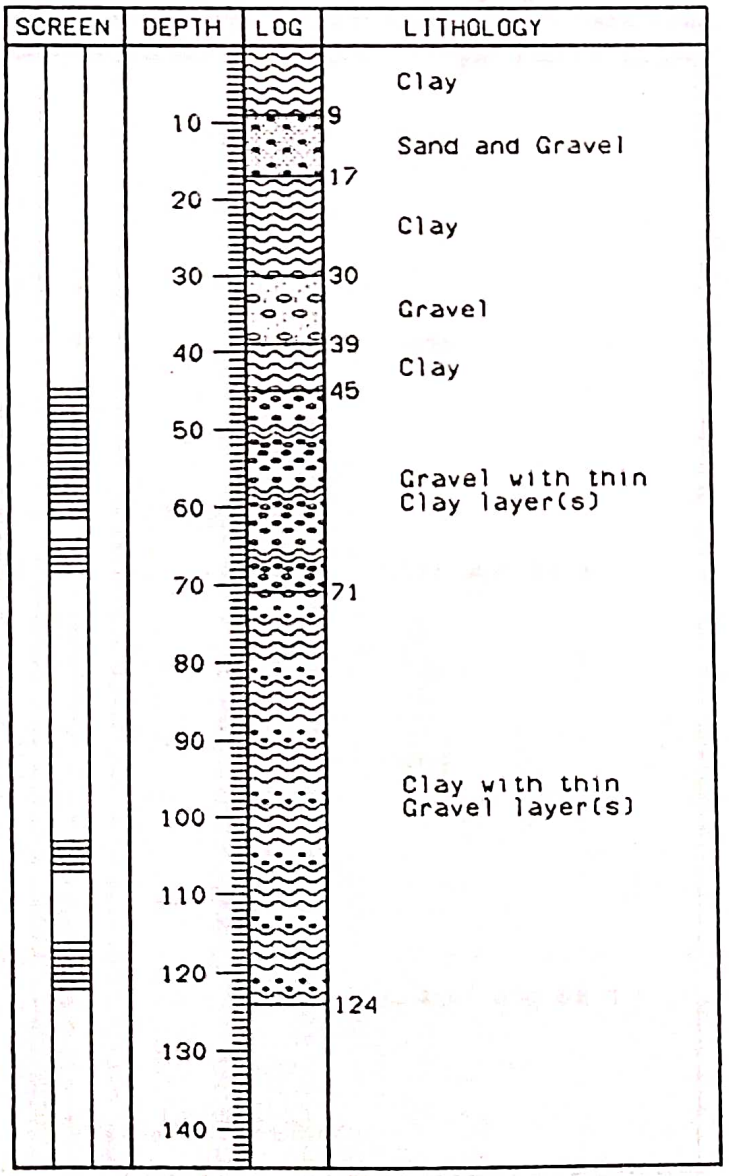


PUMPING TEST

Date: 30-31.01.86
Capacity: 127 l/sec
Duration: 20 hrs.
Transmiss.: 1410 m2/day
Method : Theis
Stor Coeff.: 3.9 E-7
SWL: 5.98 m.(A.GR.L)
DWL: 16.4 m.(B.GR.L)

Well No. BL II/23	Location: SIHAWA
Elevation: 101.9	X = 723750 Y = 3052875
Method of Drilling:	RIG
Drilling Dates :	24.01.89 - 13.02.89
Total Depth	124.00
Comments :	Well Size: 16"/10"; M.P: 0.58 m Screen Pos: 44.6 - 61.1, 64.0 - 68.0 103.0 - 107.0, 116.0 - 122.0 Drilled Under: BLGWP

W E L L L O G

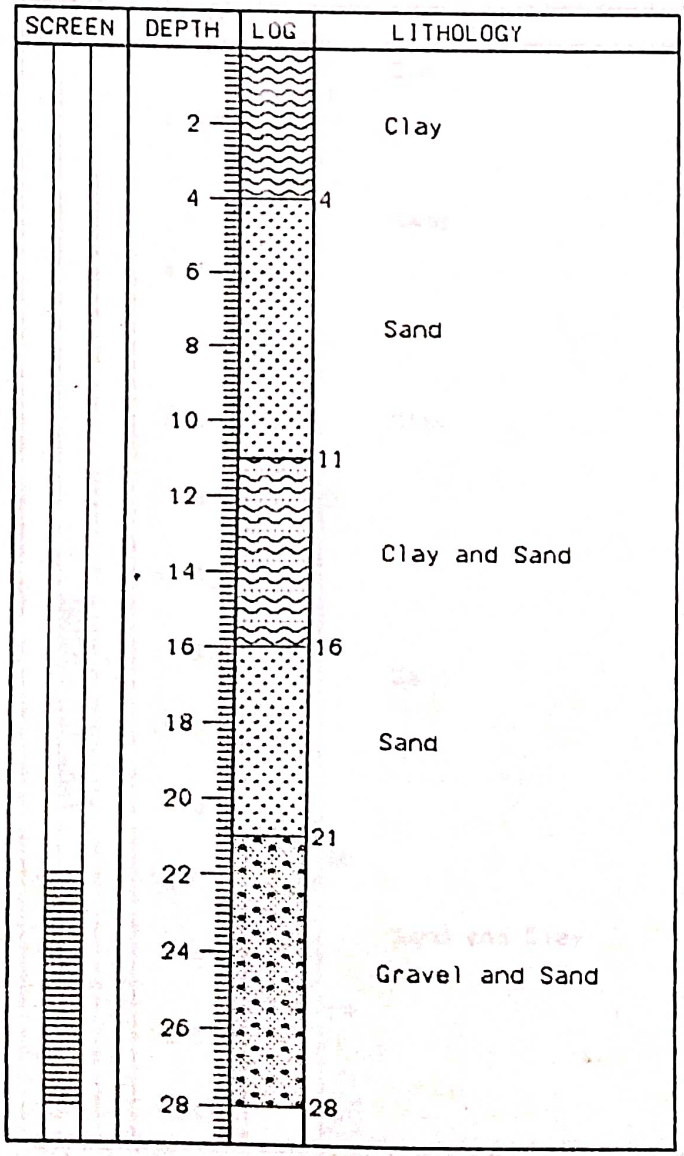


GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. JR A/62	Location: MASINA
Elevation: 102.1	X = 721500 Y = 3046500
Method of Drilling: RIG	
Drilling Dates : 26.01.84 - 27.01.84	
Total Depth : 28.00	
Comments : Well Size: 6"/4" Screen Position: 22 - 28 m. Drilled Under: Japanese Red Cross	

WELL LOG



PUMPING TEST

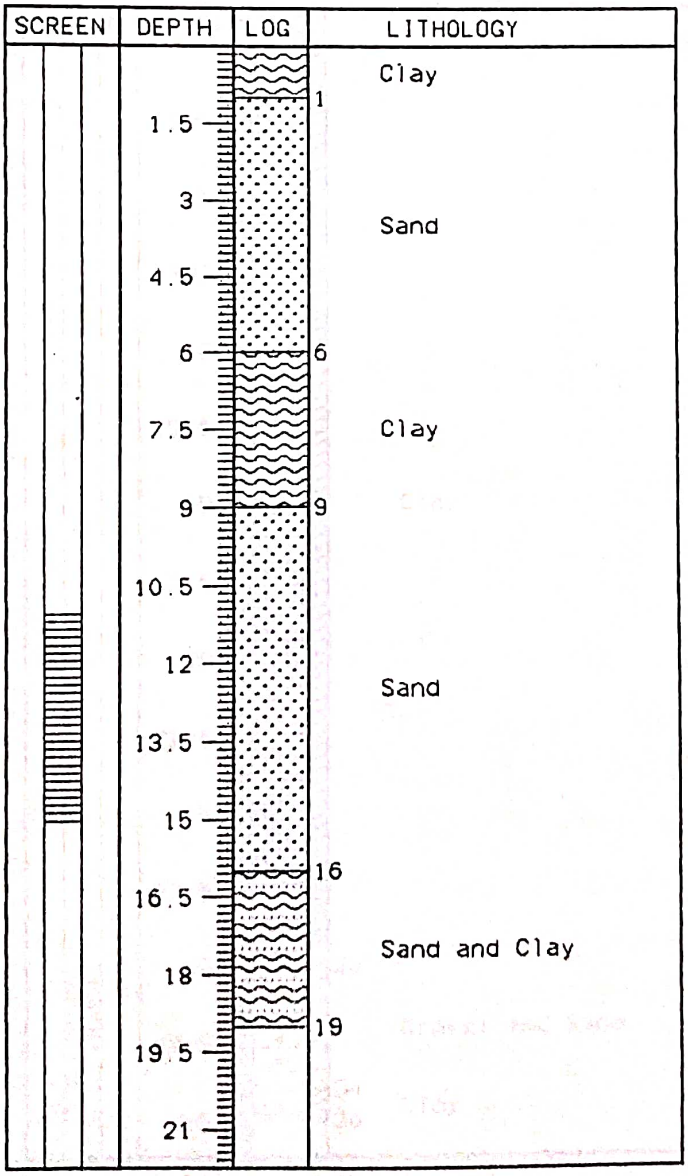
SWL: 3.4 m.(B.GR.L)
DWL: 4.0 m.(B.GR.L)

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. JR A/67	Location: MAJGAW
Elevation: 98.1	X = 732750 Y = 3037875
Method of Drilling: RIG	
Drilling Dates : 08.02.84 - 09.02.84	
Total Depth : 19.00	
Comments : Well Size: 6"/4" Screen Position: 11 - 15 m. Drilled Under: Japanese Red Cross	

W E L L L O G



PUMPING TEST

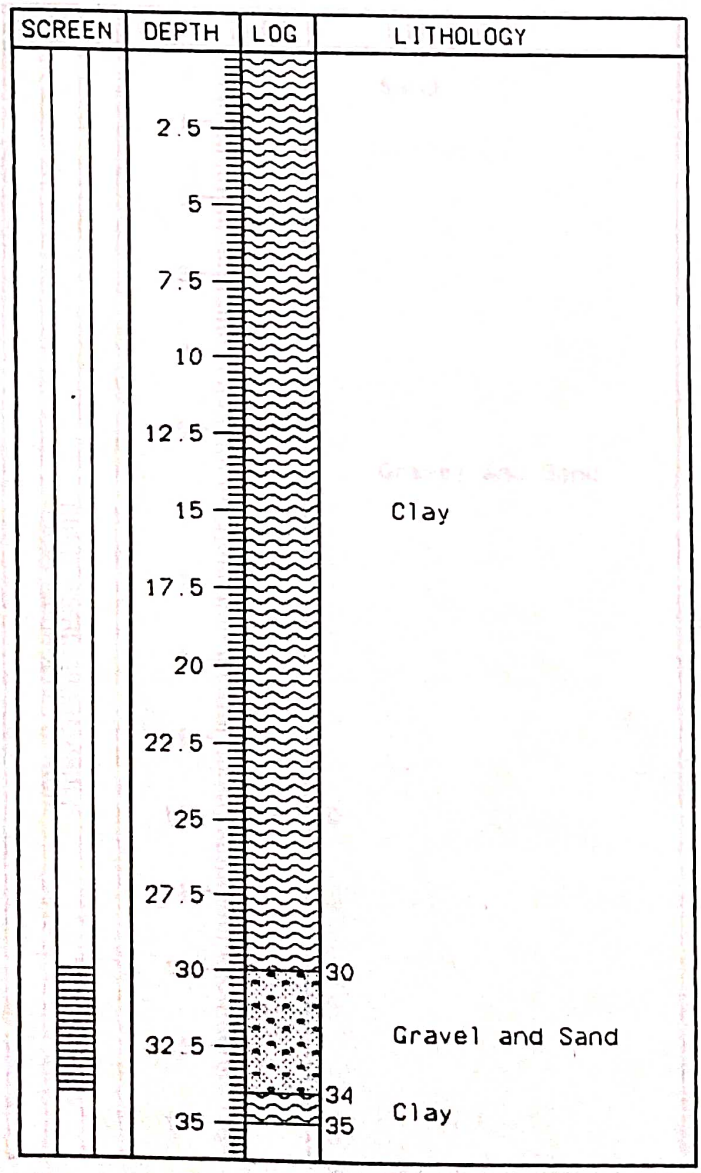
SWL: 2.4 m.(B.GR.L)
DWL: 7.0 m.(B.GR.L)

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. JR A/76	Location: DUDHARCHH
Elevation: 138.7	X = 729750 Y = 3065250
Method of Drilling: RIG	
Drilling Dates : 22.02.84 - 23.02.84	
Total Depth : 35.00	
Comments : Well Size: 6"/4" Screen Position: 30 - 34 m. Drilled Under: Japanese Red Cross	

W E L L L O G

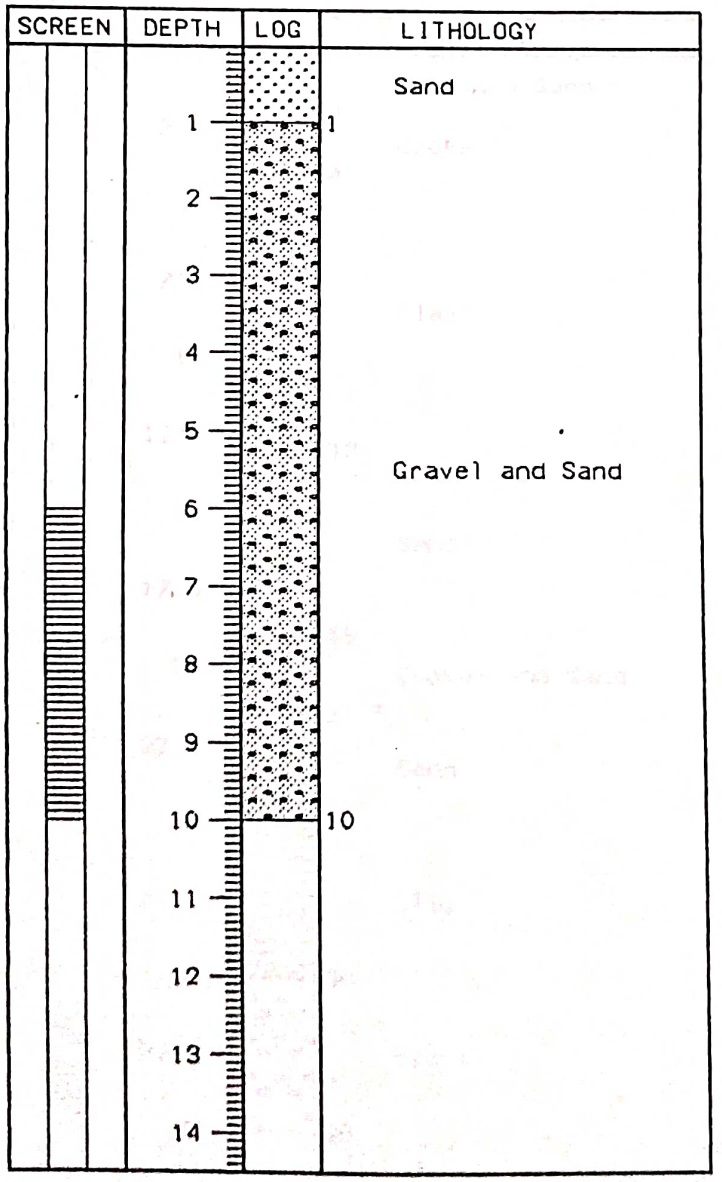


PUMPING TEST

SWL: 1.9 m.(B.GR.L)
DWL: 7.0 m.(B.GR.L)

Well No. JR B/24	Location: KHAIRENI
Elevation: 146.6	X = 756500 Y = 3061500
Method of Drilling: RIG	
Drilling Dates : 04.09.83 - 09.09.83	
Total Depth : 10.00	
Comments : Well Size: 6"/4" Screen Position: 6 - 10 m. Drilled Under: Japanese Red Cross	

W E L L L O G



PUMPING TEST

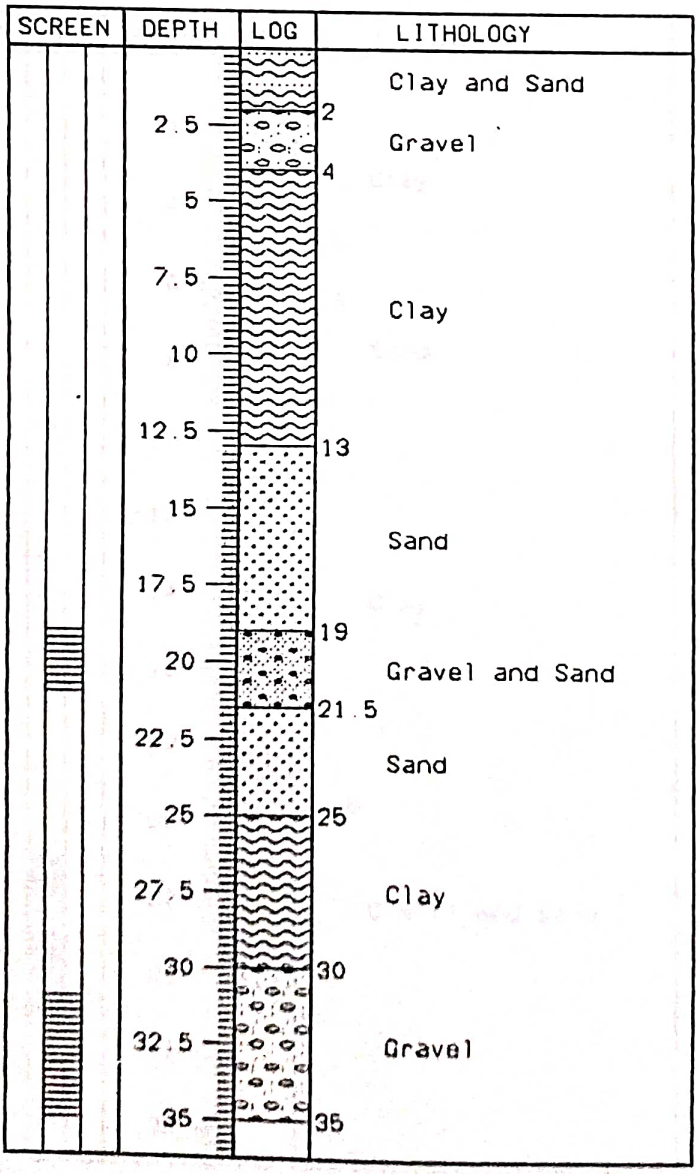
SWL: 2.0 m.(B.GR.L)
DWL: 4.5 m.(B.GR.L)

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. JR B/75	Location: BANKATTI
Elevation: 140.2	X = 724250 Y = 3063875
Method of Drilling: RIG	
Drilling Dates : 22.02.84 - 26.02.84	
Total Depth : 35.00	
Comments : Well Size: 6"/4" Screen Position: 19 - 21 m. 31 - 35 m. Drilled Under: Japanese Red Cross	

W E L L L O G



PUMPING TEST

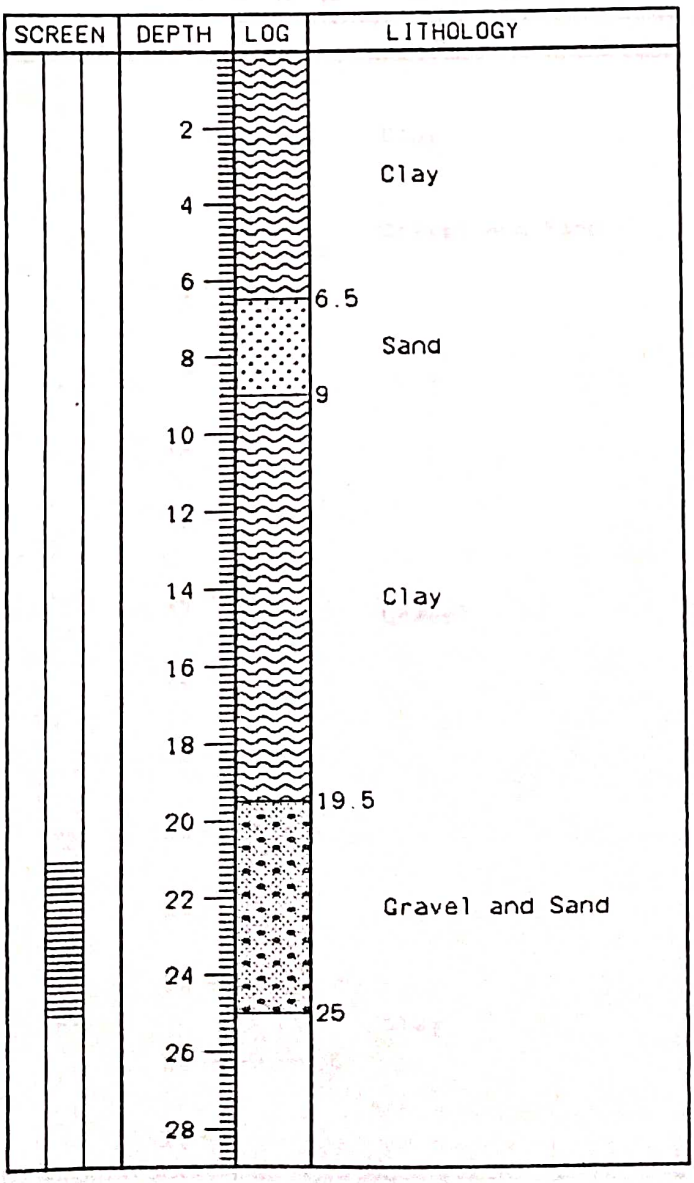
SWL: 8.0 m.(B.GR.L)
DWL: 9.4 m.(B.GR.L)

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. JR B/81	Location: NARENAPUR
Elevation: 121.9	X = 734625 Y = 3062125
Method of Drilling: RIG	
Drilling Dates : 18.03.84 - 19.03.84	
Total Depth : 25.00	
Comments : Well Size: 6"/4" Screen Position: 21 - 25 m. Drilled Under: Japanese Red Cross	

W E L L L O G

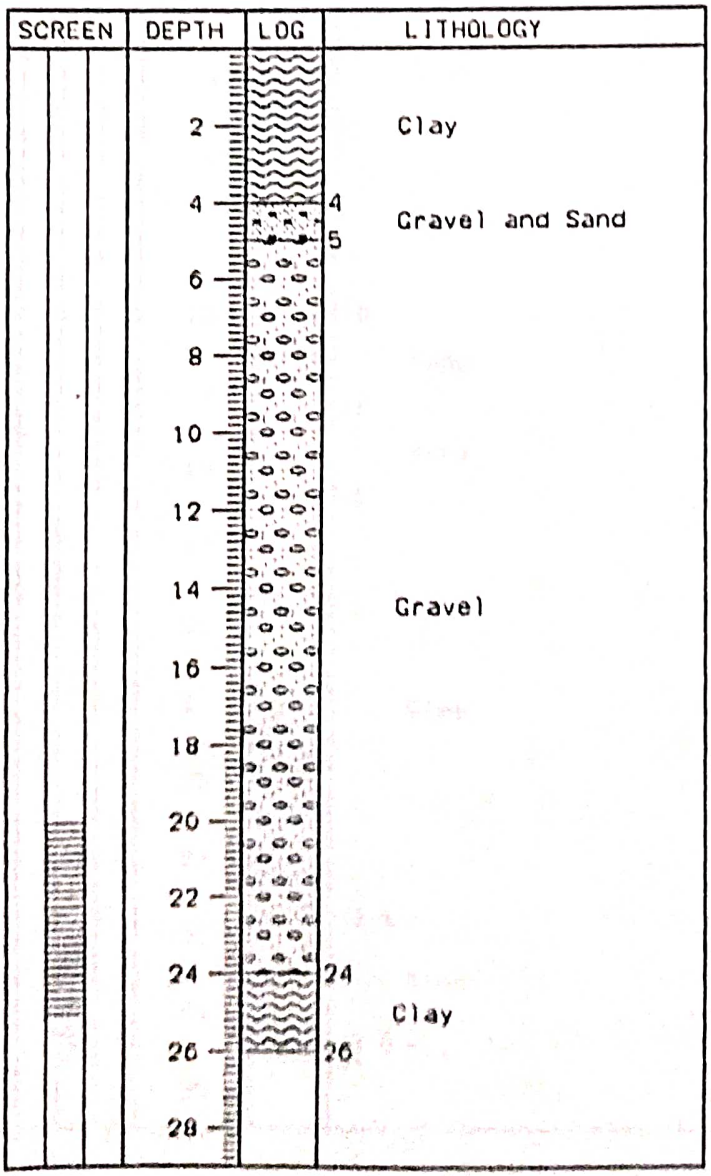


PUMPING TEST

SWL: 1.8 m.(B.GR.L)
DWL: 2.2 m.(B.GR.L)

Well No. JR B/96	Location MIRGAULI
Elevation: 128	X = 750375 Y = 3057625
Method of Drilling: RIG	
Drilling Dates: 28.05.84 - 30.05.84	
Total Depth: 26.00	
Comments: Well Size: 6"/4" Screen Position: 20 - 25 m. Drilled Under: Japanese Red Cross	

W E L L L O G



PUMPING TEST

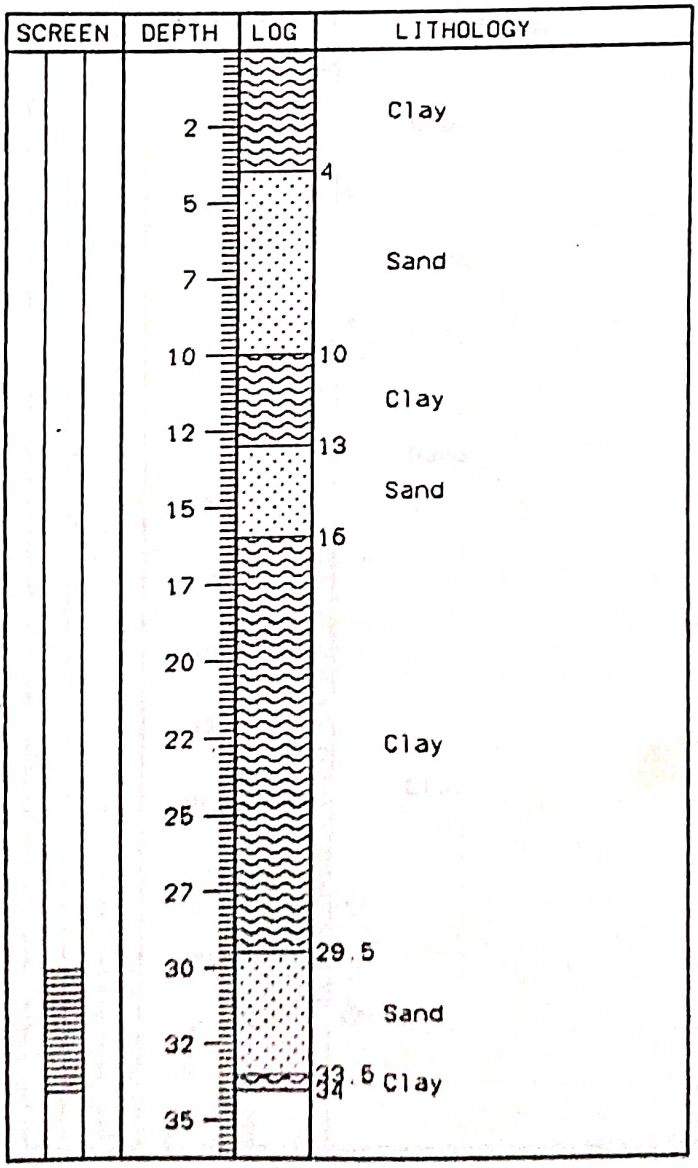
SWL: 3.0 m.(B.GR.L)
DWL: 3.5 m.(B.GR.L)

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. JR C/72	Location: NANDNAGAR
Elevation: 95.4	X = 721625 Y = 3038125
Method of Drilling: RIG	
Drilling Dates : 02.02.84 - 04.02.84	
Total Depth : 34.00	
Comments : Well Size: 6"/4" Screen Position: 30 - 34 m. Drilled Under: Japanese Red Cross	

W E L L L O G

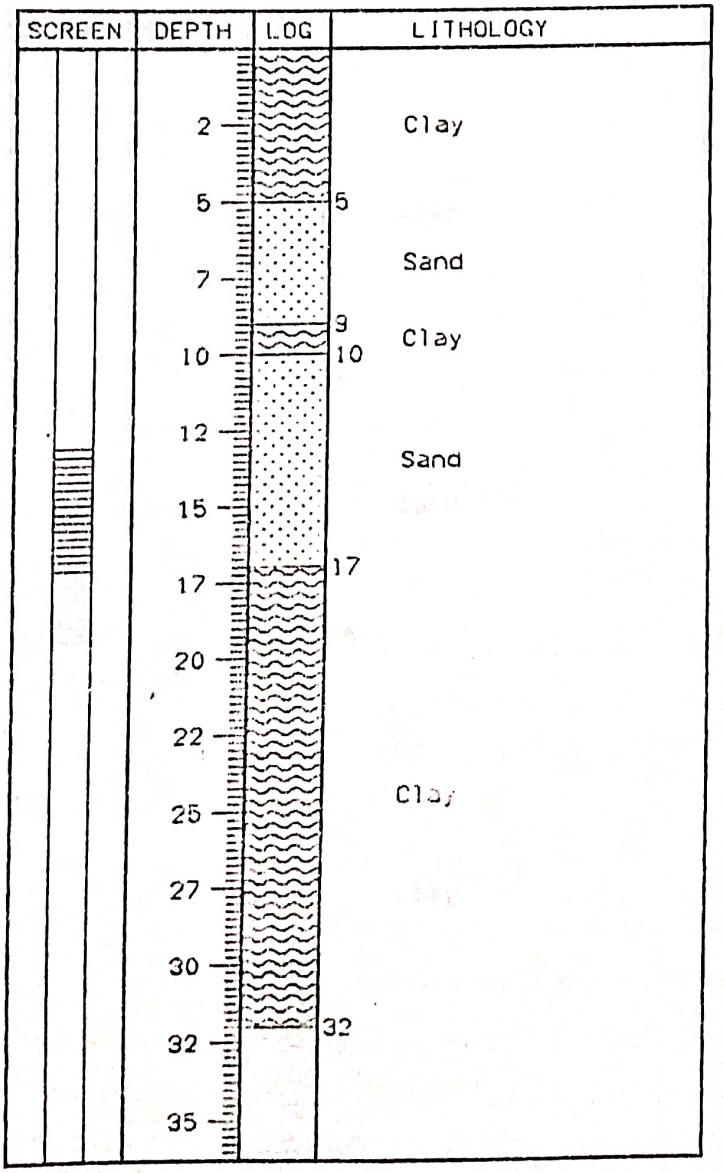


PUMPING TEST

SWL: 3.3 m.(B.GR.L)
DWL: 4.6 m.(B.GR.L)

Well No JR C/73	Location: ARDOLA
Elevation: 93.9	X = 724500 Y = 3035625
Method of Drilling: RIG	
Drilling Dates : 06.02.84 - 07.02.84	
Total Depth : 32.00	
Comments : Well Size: 6"/4" Screen Position: 13 - 17 m. Drilled Under: Japanese Red Cross	

W E L L L O G

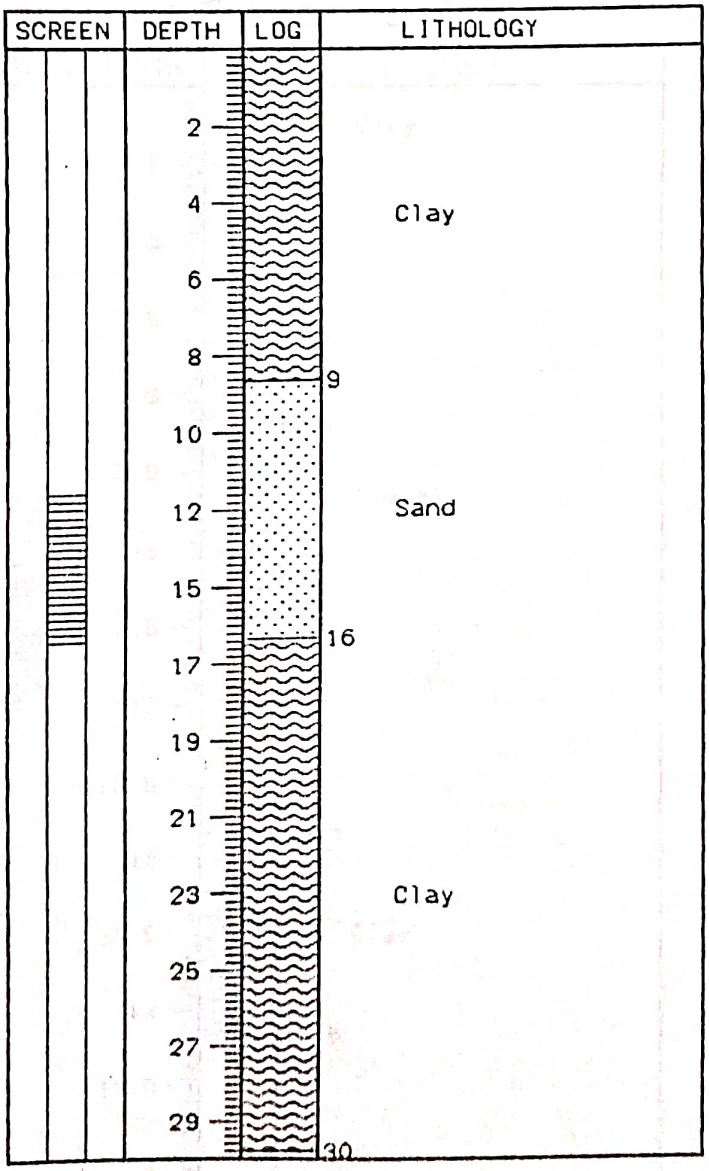


PUMPING TEST

SWL: 4.5 m.(B.GR.L)
DWL: 7.0 m.(B.GR.L)

Well No. JR C/75	Location: MAHADEI
Elevation: 93.3	X = 729625 Y = 3032125
Method of Drilling: RIG	
Drilling Dates : 08.02.84 - 09.02.84	
Total Depth : 30.00	
Comments : Well Size: 6"/4" Screen Position: 12 - 16 m. Drilled Under: Japanese Red Cross	

W E L L L O G



PUMPING TEST

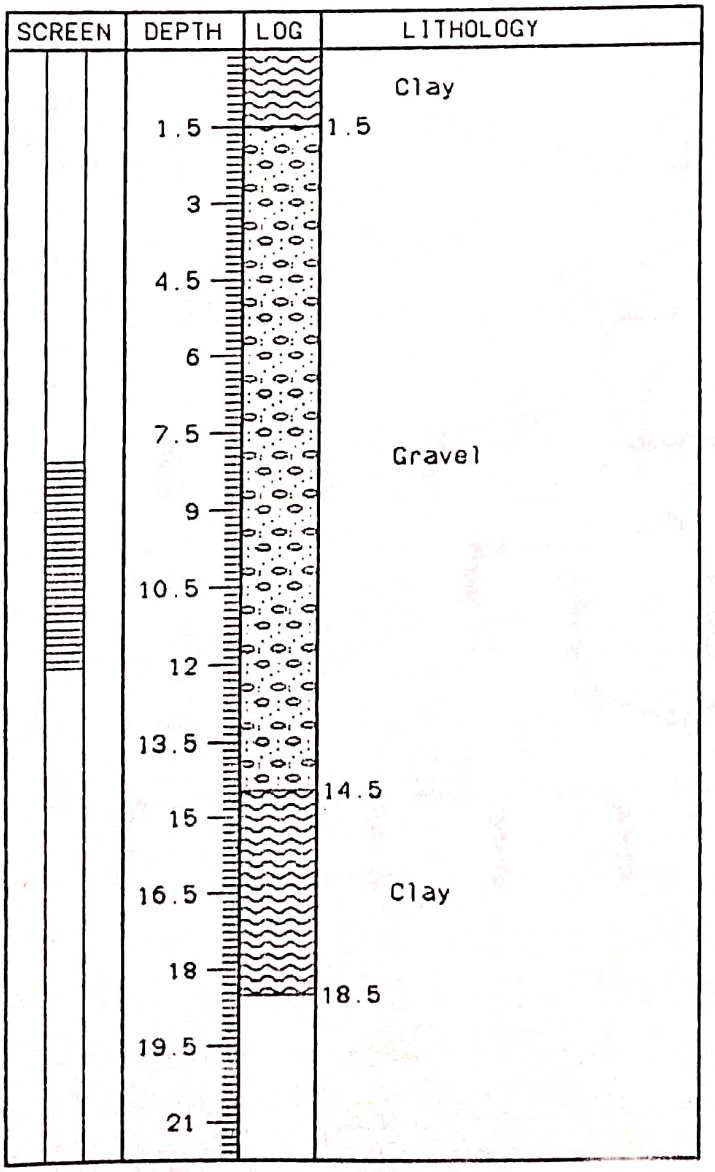
SWL: 3.0 m.(B.GR.L)
DWL: 3.9 m.(B.GR.L)

GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

"GROUND WATER EXPLORATION IN TERAI"

Well No. JR C/93	Location: BHARIYA
Elevation: 145.1	X = 738875 Y = 3062750
Method of Drilling: RIG	
Drilling Dates : 30.03.84 - 31.03.84	
Total Depth : 18.50	
Comments : Well Size: 6"/4" Screen Position: 8 - 12 m. Drilled Under: Japanese Red Cross	

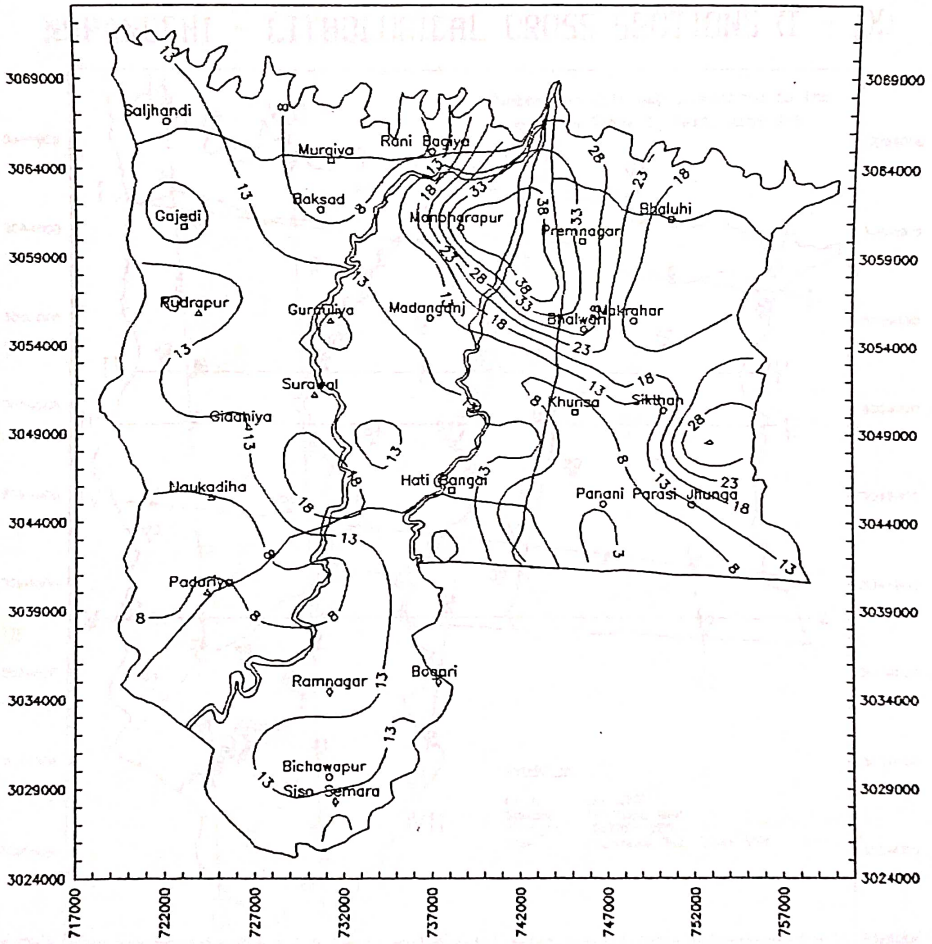
W E L L L O G



PUMPING TEST

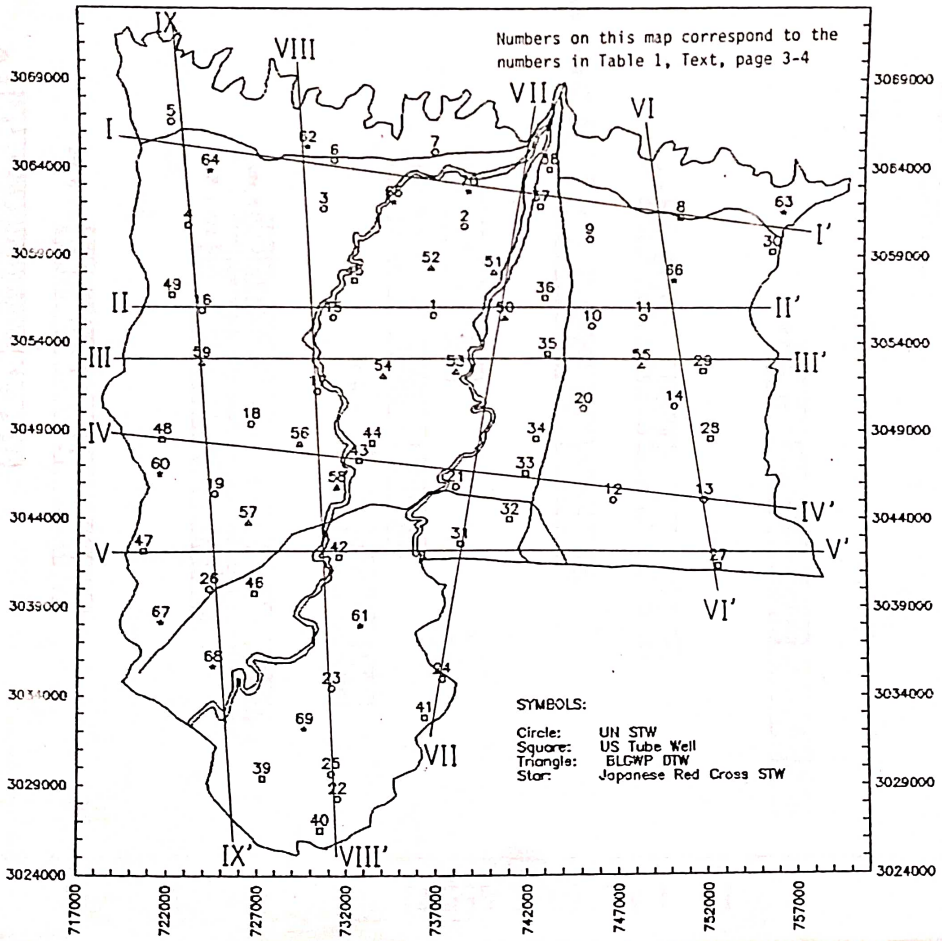
SWL: 9.7 m. (B.GR.L)
DWL: 10.0 m.(B.GR.L)

AQUIFER THICKNESS WITHIN 47 M. DEPTH

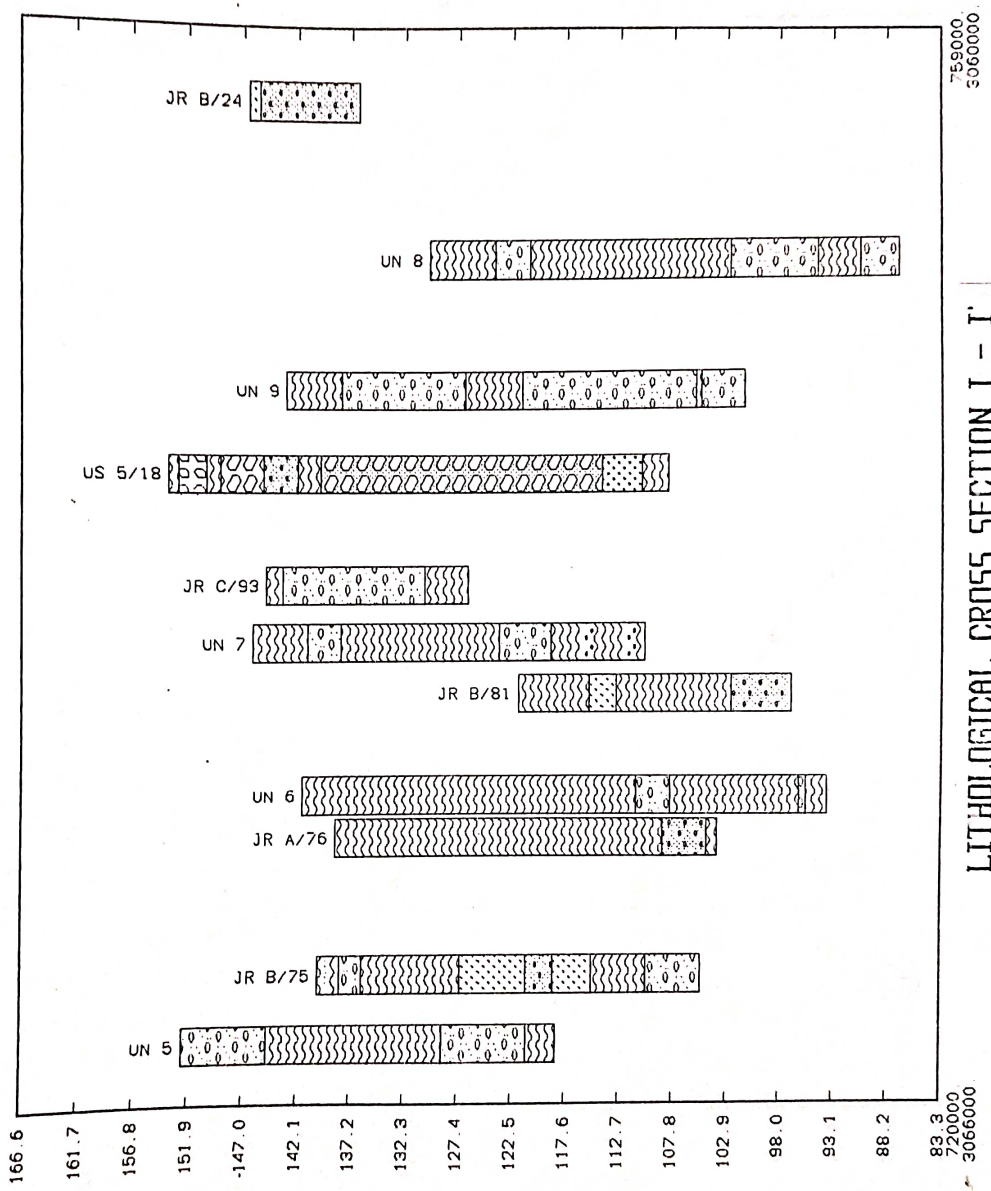


APPENDIX 3A

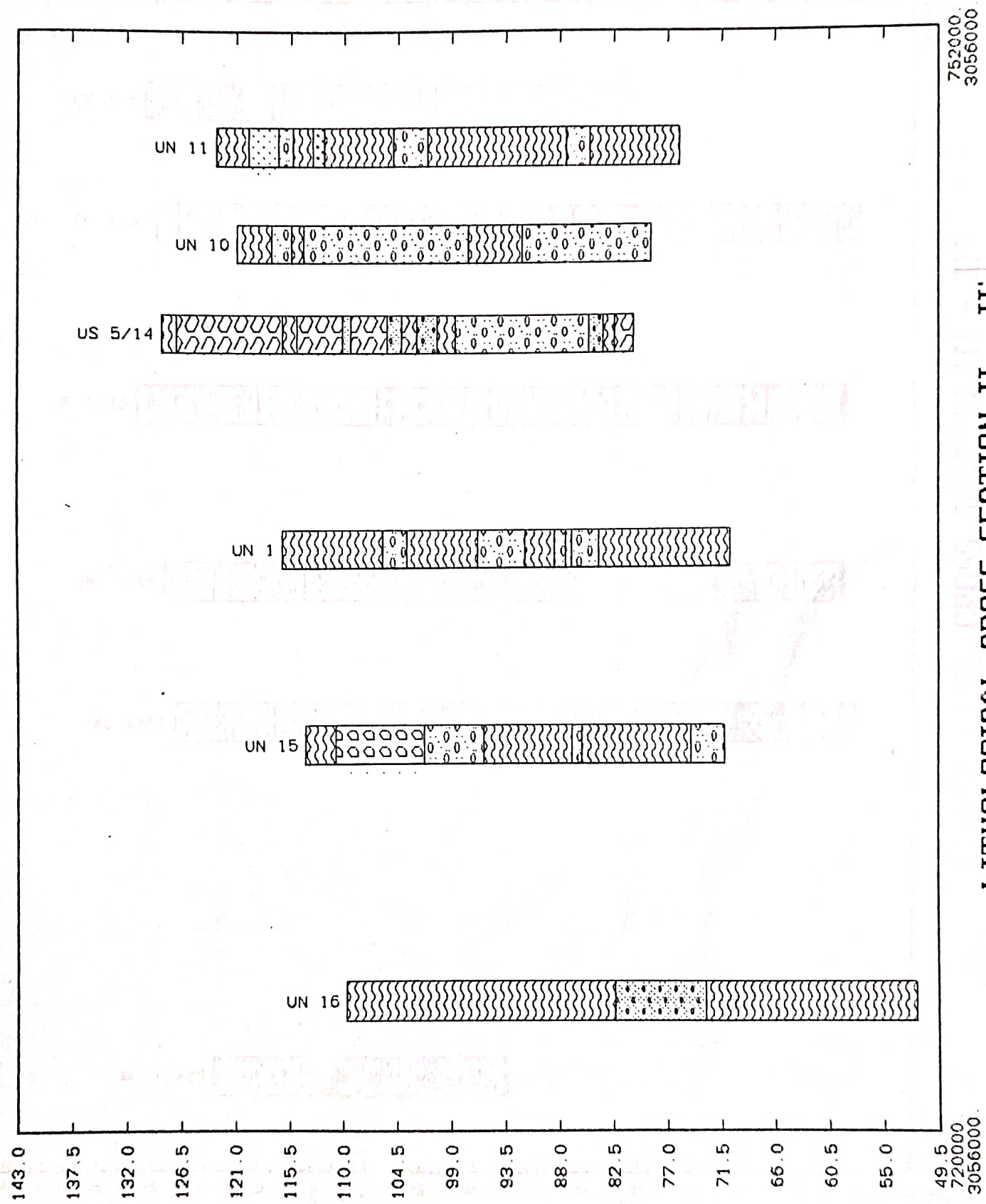
RUPANDEHI - LITHOLOGICAL CROSS SECTIONS (I - IX)



APPENDIX 4/1

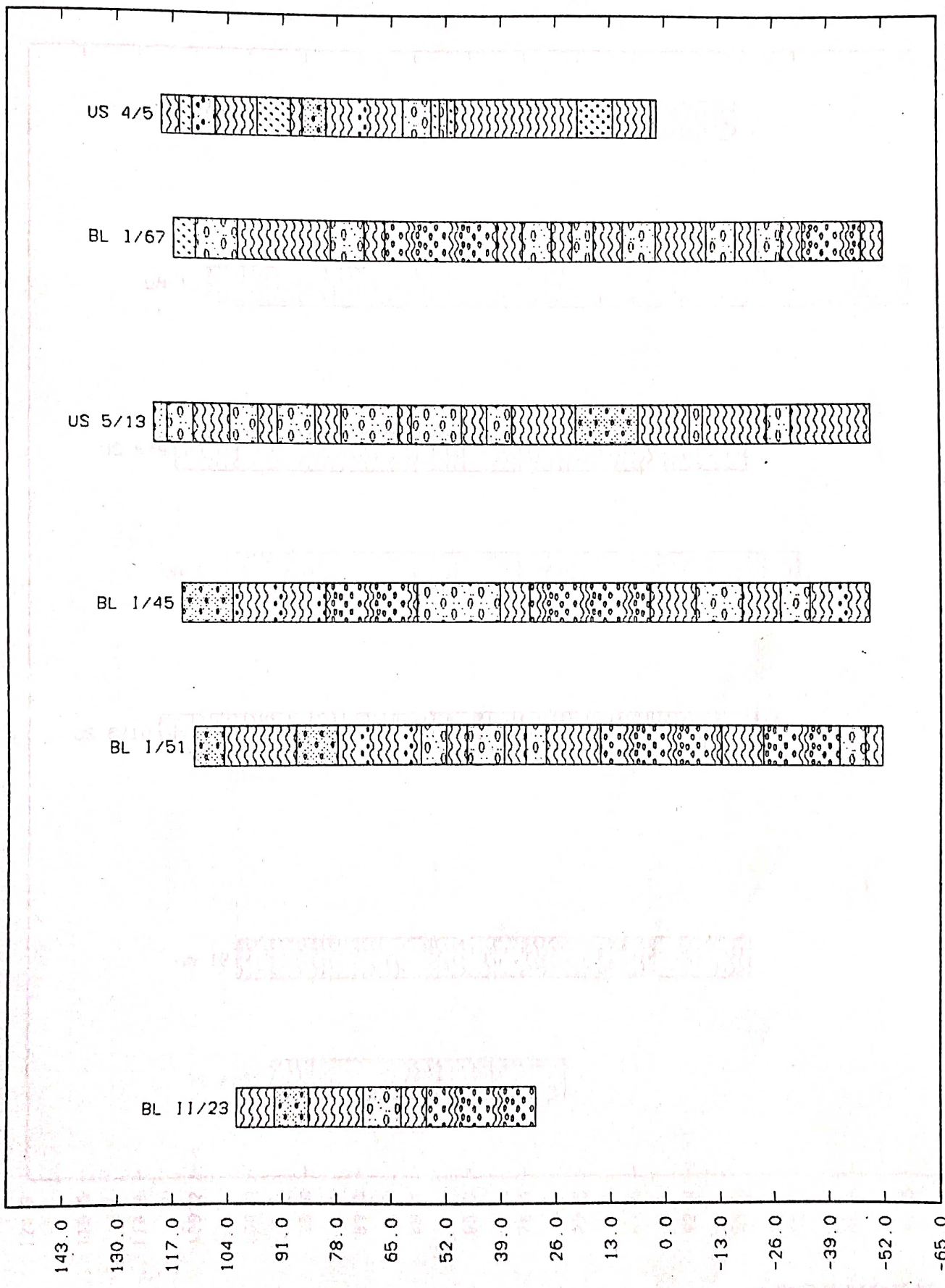


LITHOLOGICAL CROSS SECTION I - I'

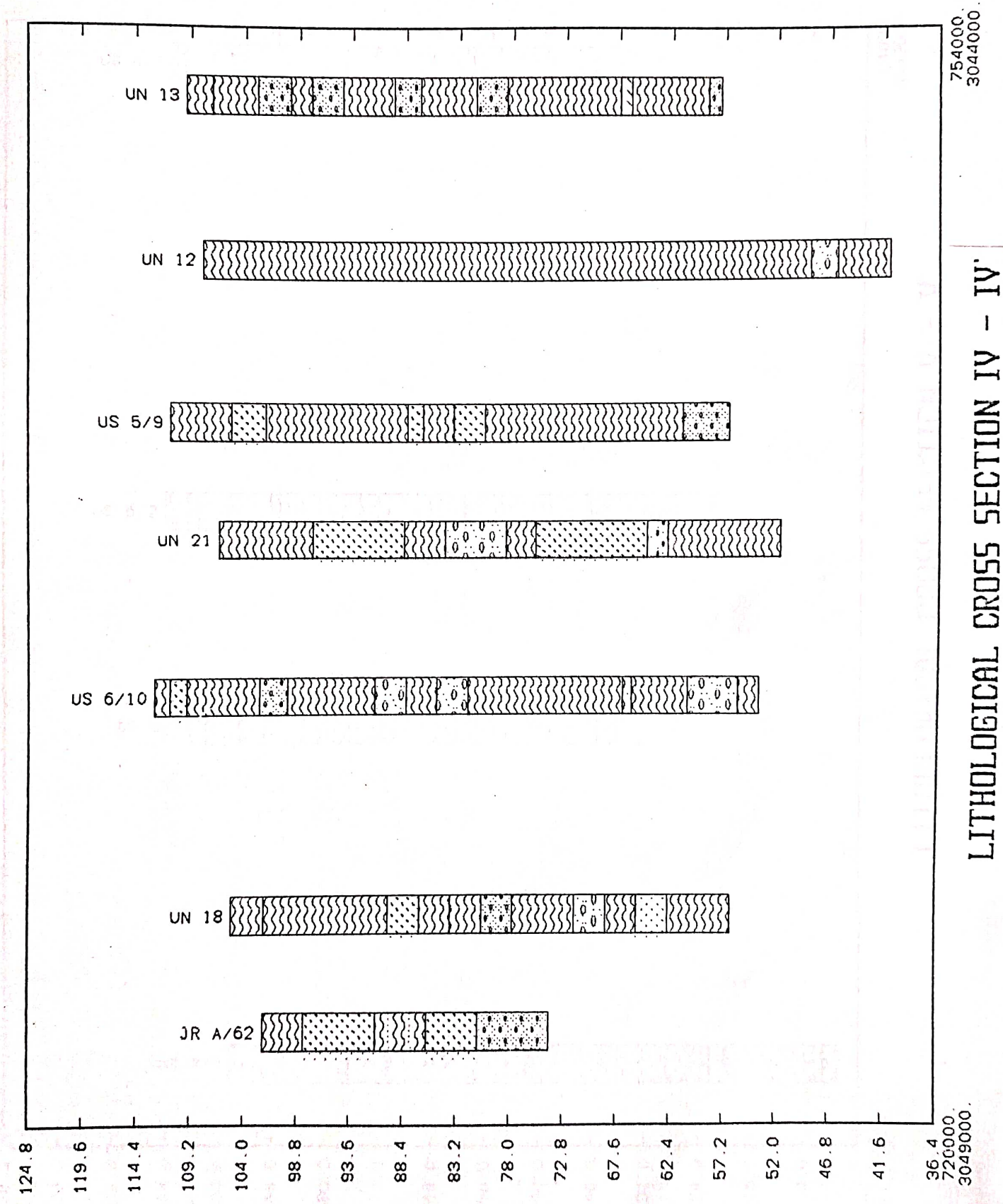


LITHOLOGICAL CROSS SECTION II - II'

APPENDIX 4/3



LITHOLOGICAL CROSS SECTION III - III'

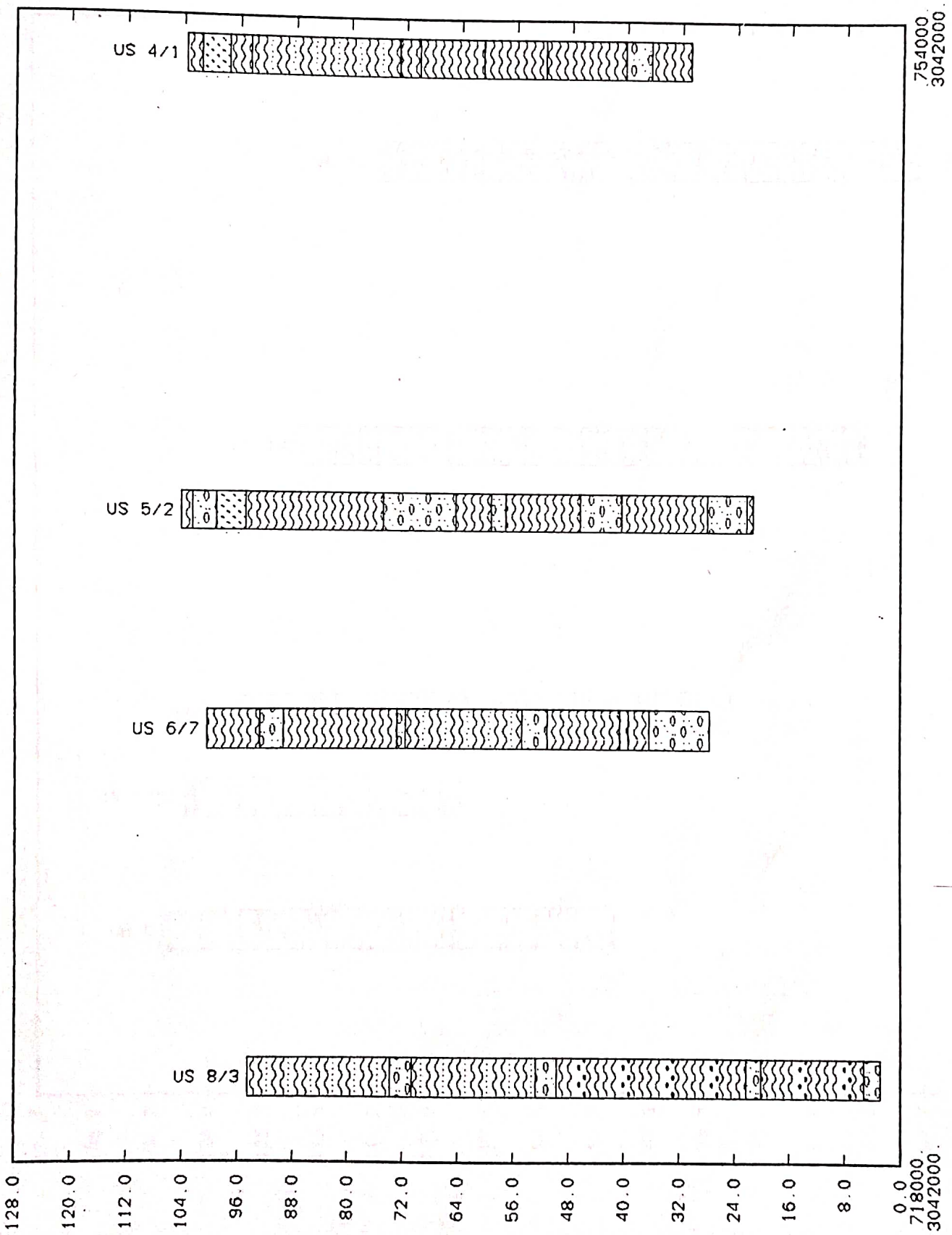


LITHOLOGICAL CROSS SECTION IV - IV'

APPENDIX 4/5

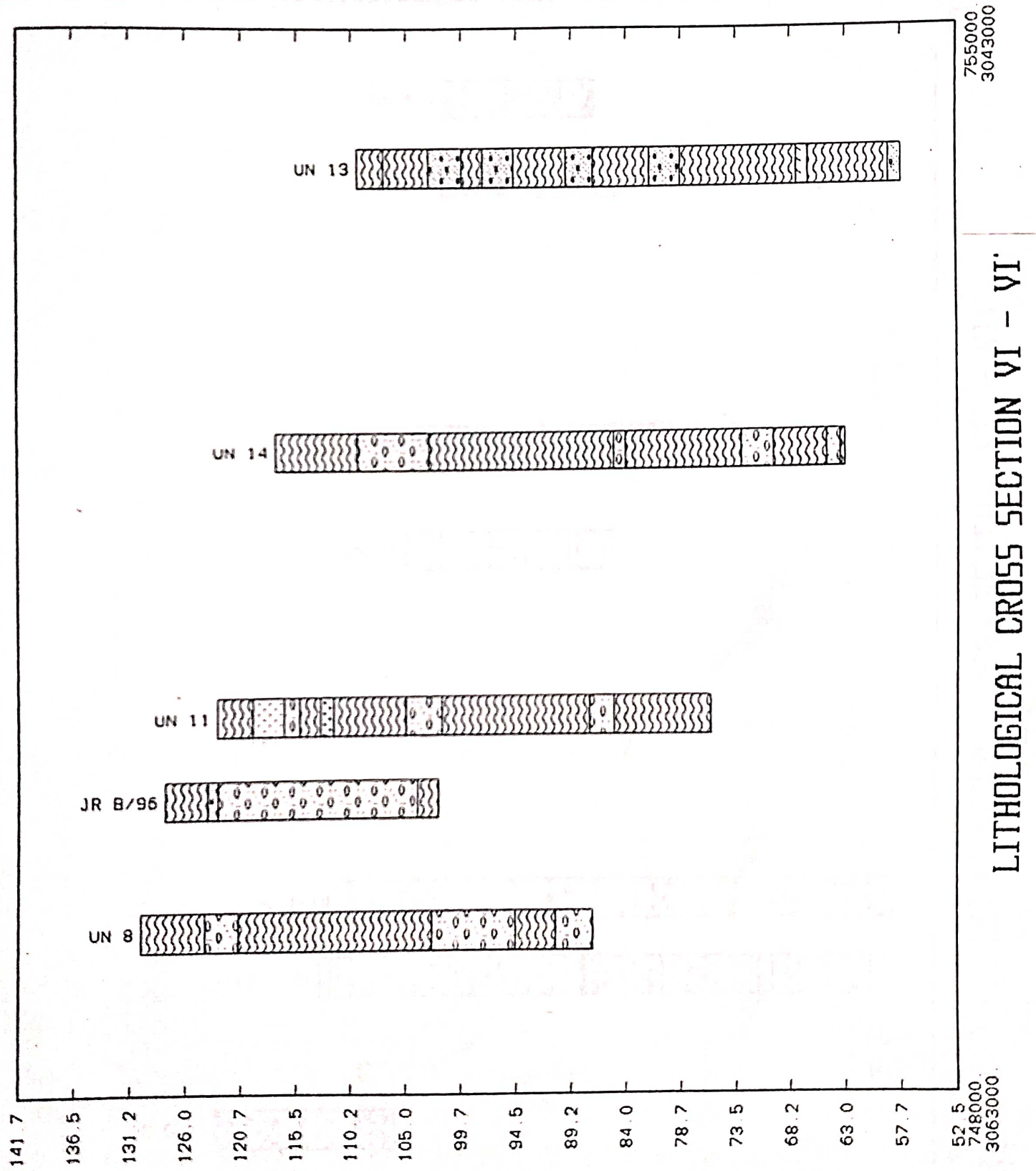
GWRDB - UN/DTCD NEP/86/025 RUPANDEHI

GROUND WATER INVESTIGATIONS IN TERAI

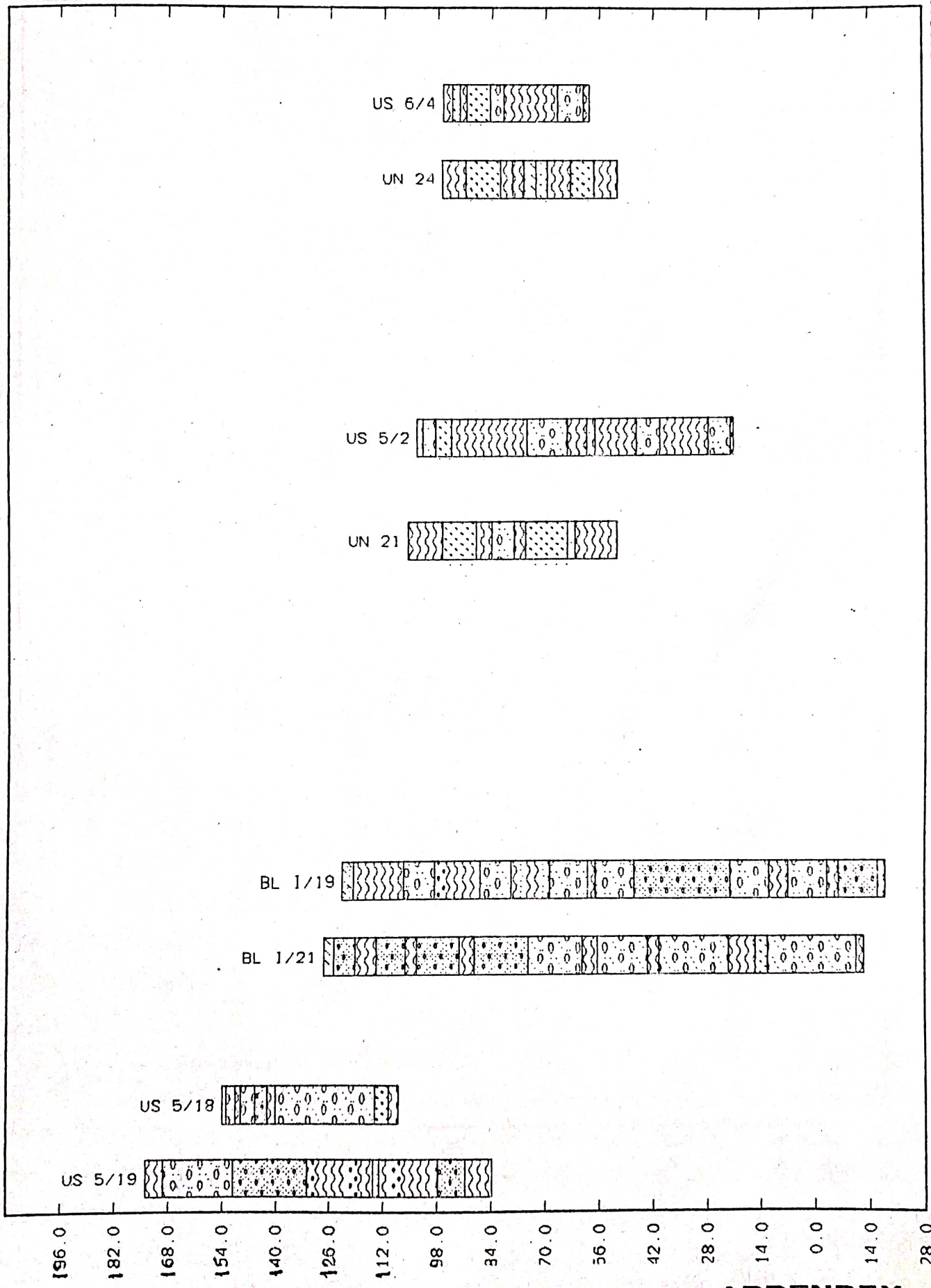


LITHOLOGICAL CROSS SECTION Y - Y'

APPENDIX 4/6

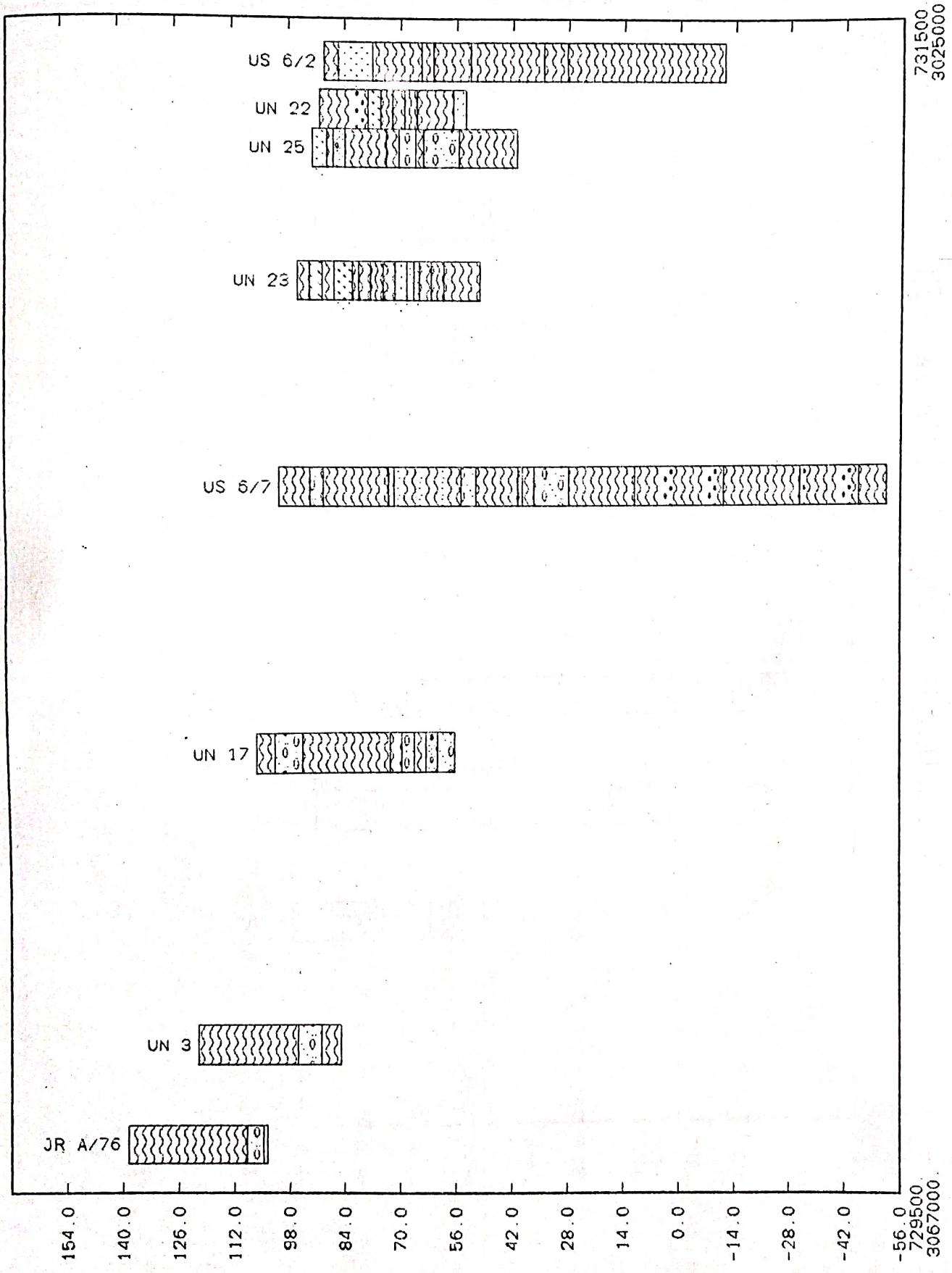


LITHOLOGICAL CROSS SECTION VI - VI'

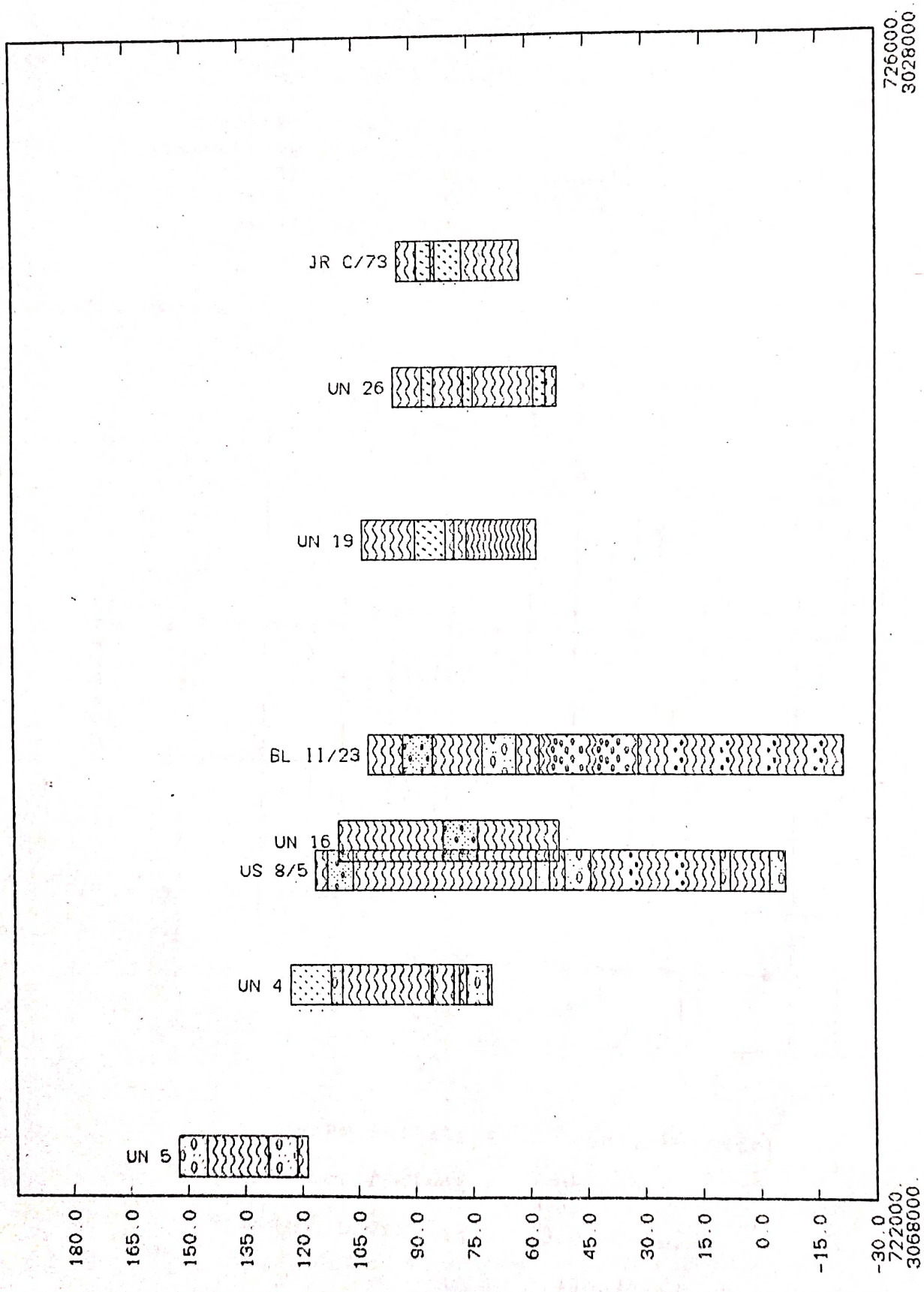


LITHOLOGICAL CROSS SECTION VII - VII'

APPENDIX 4/8



LITHOLOGICAL CROSS SECTION VIII - VIII'

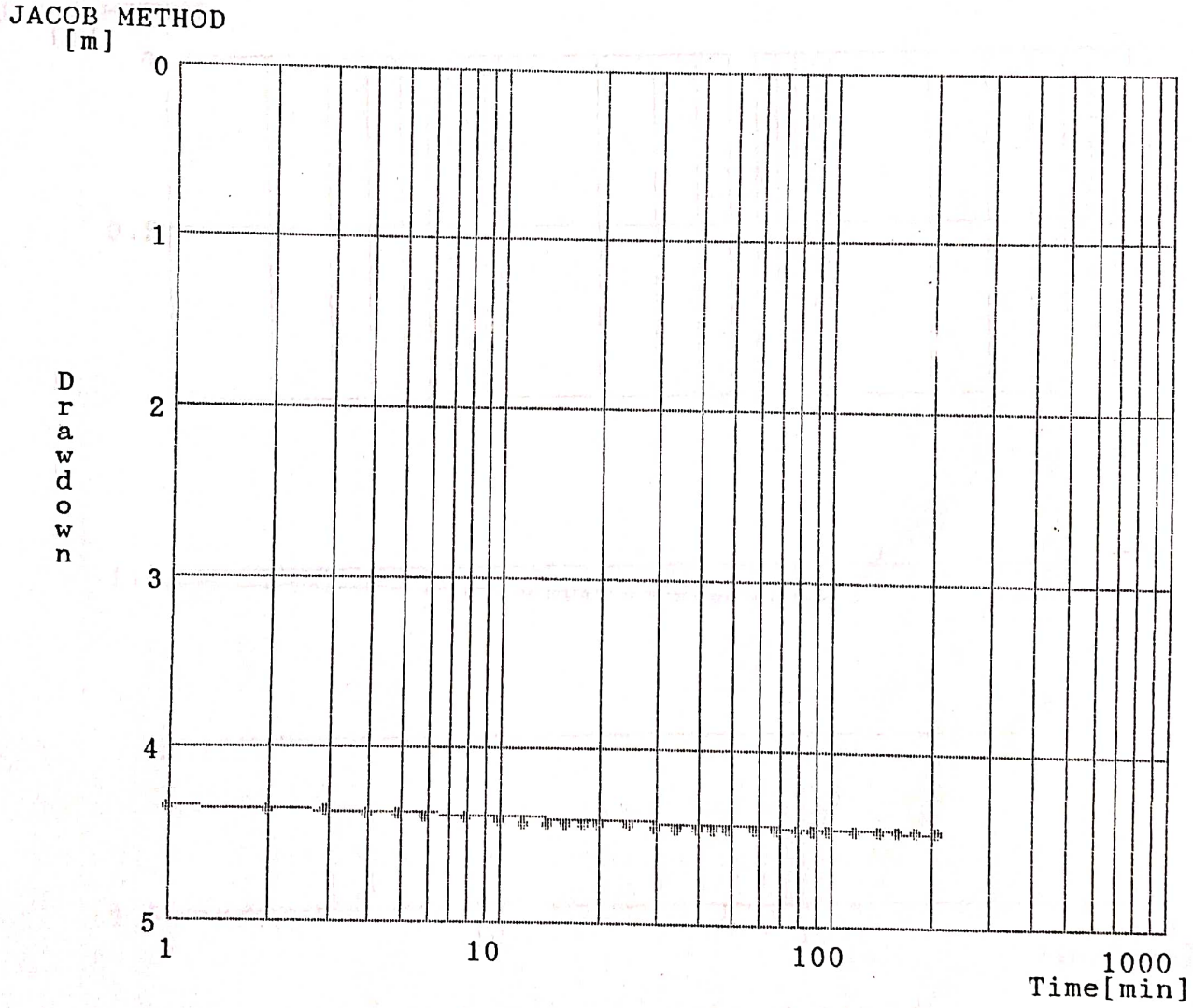


LITHOLOGICAL CROSS SECTION IX - IX'

Project : UNDP/NEP/86/025
Organization : UNDTCD/GWRDB

Test : UN 1 - MADANGANJ

Constant Pumping Rate = 12.000 [l/sec]
Distance from Pumping Well = 0.05 [m]
Type of Aquifer = CONFINED
Type of Input Data = LEVEL
Static Water Level = -3.25 [m]
Well Type = STANDARD



Transmissivity = 3691. [m2/day]

Storage Coefficient = 0.00000000

Standard Deviation = 0.0120 [m]

A0 = 0.434285E+01

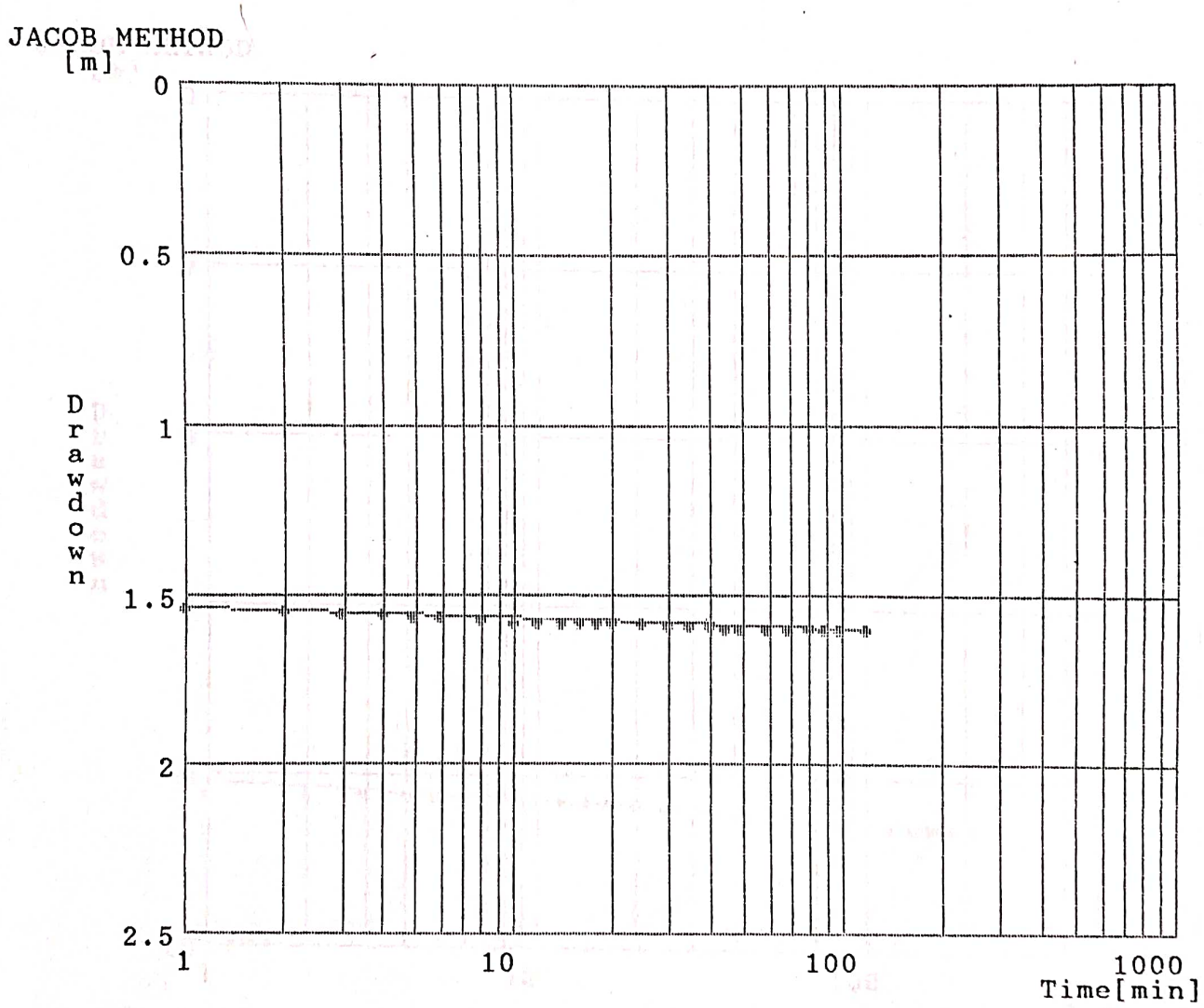
A1 = 0.514069E-01

Number of Points = 29 of 29

Project : UNDP/NEP/86/025
Organization : UNDTCD/GWRDB

Test : UN 2 - MANOHARPUR

Constant Pumping Rate = 13.300 [l/sec]
Distance from Pumping Well = 0.05 [m]
Type of Aquifer = CONFINED
Type of Input Data = LEVEL
Static Water Level = -6.64 [m]
Well Type = STANDARD



Transmissivity = 6953. [m2/day]

Storage Coefficient = 0.00000000

Standard Deviation = 0.0048 [m]

A0 = 0.153628E+01

A1 = 0.302439E-01

Number of Points = 25 of 25

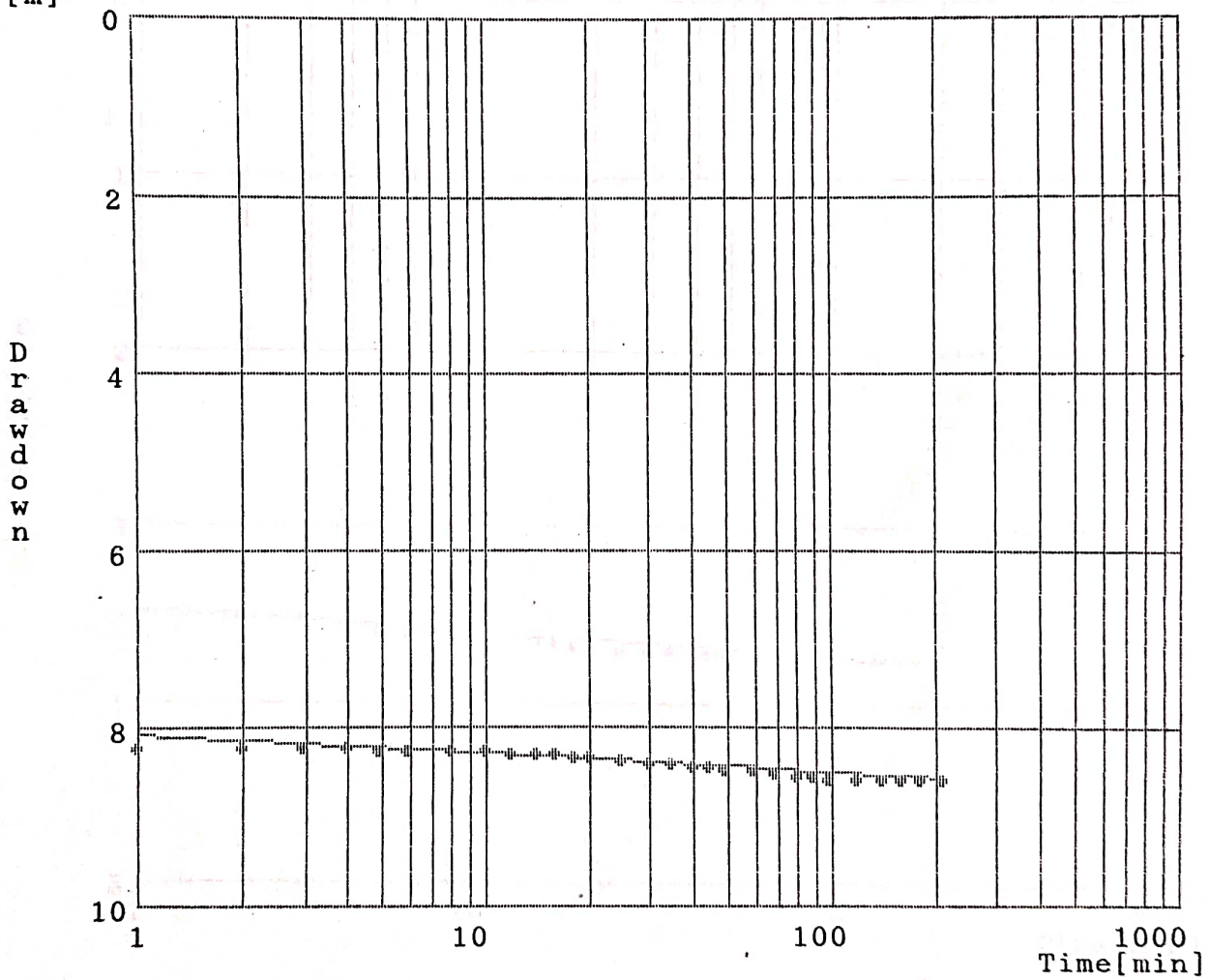
APPENDIX 5/2

Project : UNDP/NEP/86/025
Organization : UNDTCD/GWRDB

Test : UN 3 - BAKSAD

Constant Pumping Rate = 17.000 [l/sec]
Distance from Pumping Well = 0.05 [m]
Type of Aquifer = CONFINED
Type of Input Data = LEVEL
Static Water Level = 0.23 [m]
Well Type = STANDARD

JACOB METHOD



Transmissivity = 1292. [m2/day]

Storage Coefficient = 0.00000000

Standard Deviation = 0.0343 [m]

A0 = 0.808024E+01

A1 = 0.208041E+00

Number of Points = 29 of 29

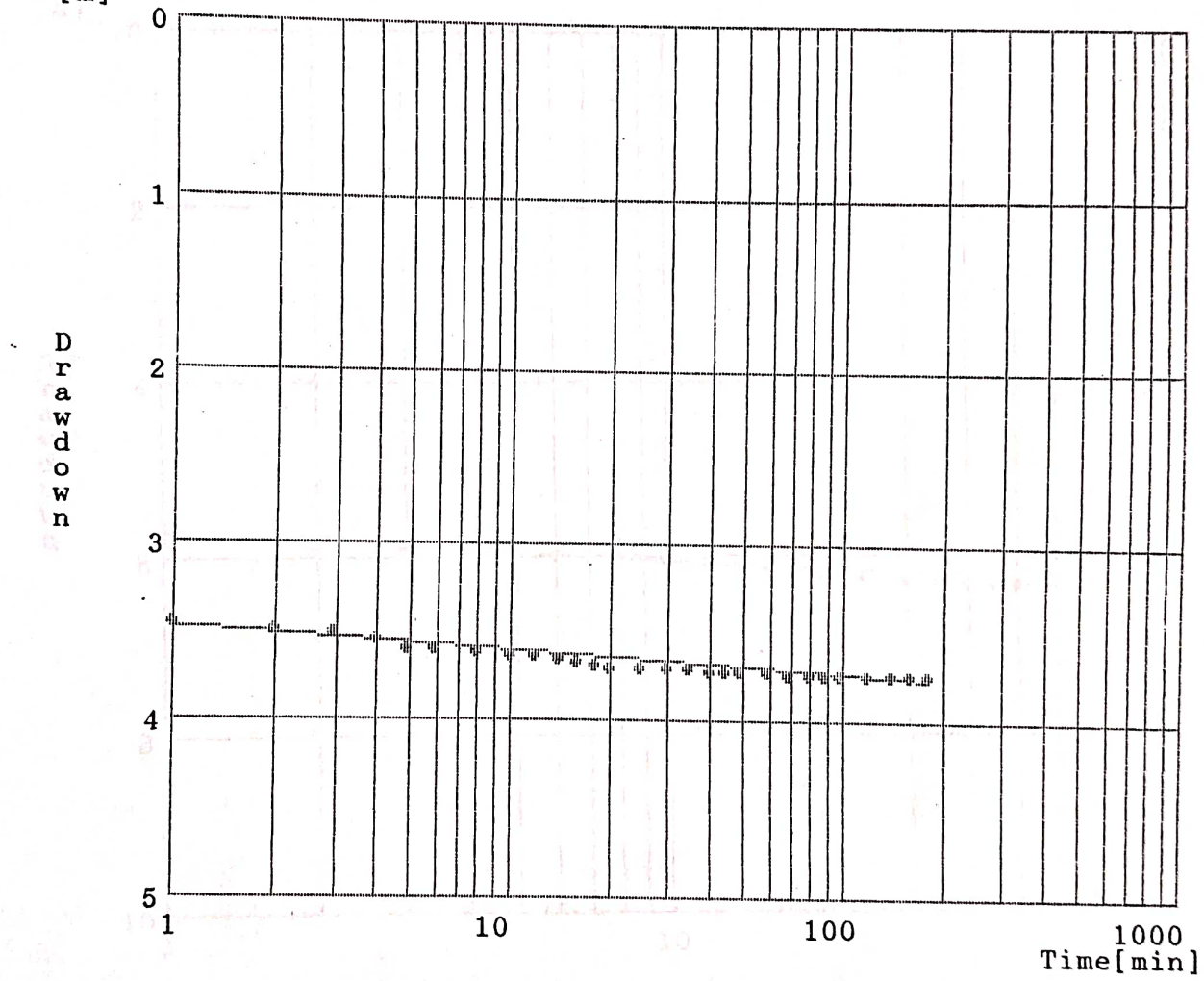
APPENDIX 5/3

Project : UNDP/NEP/86/025
Organization : UNDTCD/GWRDB

Test : UN 5 - SALJHANDI

Constant Pumping Rate = 24.000 [l/sec]
Distance from Pumping Well = 0.05 [m]
Type of Aquifer = CONFINED
Type of Input Data = LEVEL
Static Water Level = -3.10 [m]
Well Type = STANDARD

JACOB METHOD



Transmissivity = 2956. [m2/day]

Storage Coefficient = 0.00000000

Standard Deviation = 0.0264 [m]

A0 = 0.347339E+01

A1 = 0.128383E+00

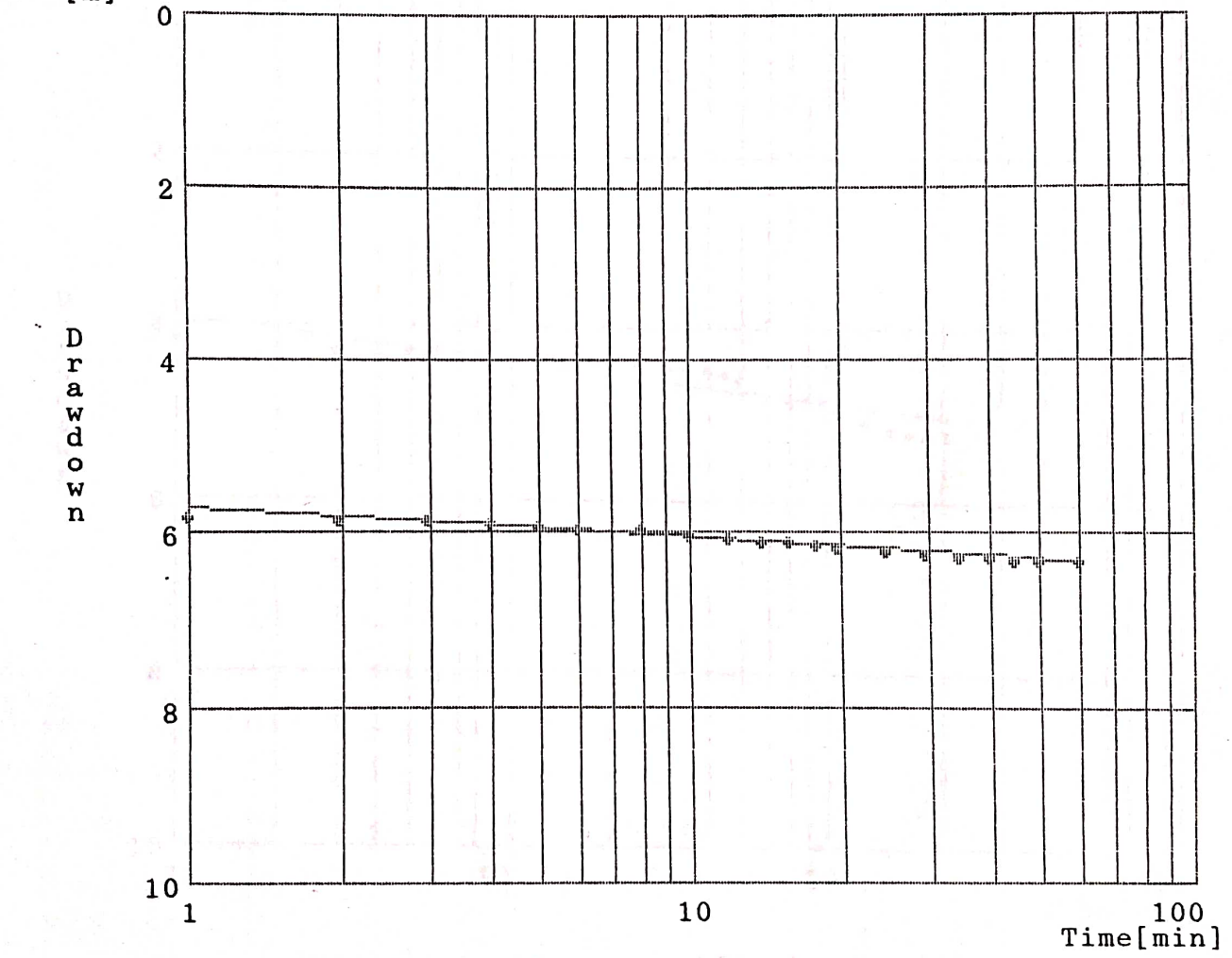
Number of Points = 28 of 28

Project : UNDP/NEP/86/025
Organization : UNDTCD/GWRDB

Test : UN 7 - RANI BAGIYA

Constant Pumping Rate = 17.000 [l/sec]
Distance from Pumping Well = 0.05 [m]
Type of Aquifer = CONFINED
Type of Input Data = LEVEL
Static Water Level = -1.64 [m]
Well Type = STANDARD

JACOB METHOD



Transmissivity = 786. [m2/day]

Storage Coefficient = 0.00000000

Standard Deviation = 0.0350 [m]

A0 = 0.570922E+01

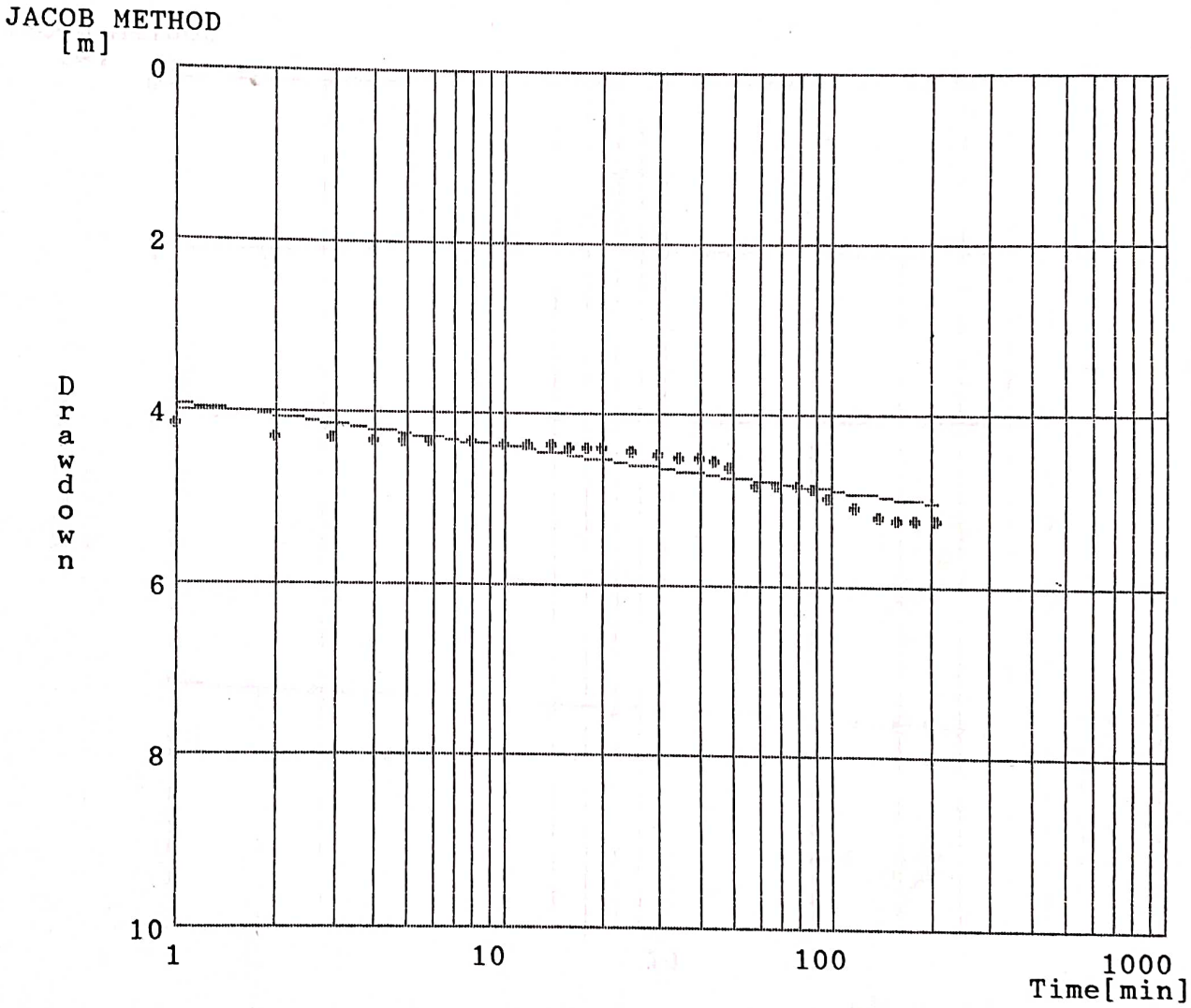
A1 = 0.342070E+00

Number of Points = 20 of 20

Project : UNDP/NEP/86/025
Organization : UNDTCD/GWRDB

Test : UN 8 - BHALUHI

Constant Pumping Rate = 17.000 [l/sec]
Distance from Pumping Well = 0.05 [m]
Type of Aquifer = CONFINED
Type of Input Data = LEVEL
Static Water Level = 0.73 [m]
Well Type = STANDARD



Transmissivity = 551. [m2/day]

Storage Coefficient = 0.00000353

Standard Deviation = 0.1421 [m]

A0 = 0.390262E+01

A1 = 0.487946E+00

Number of Points = 29 of 29

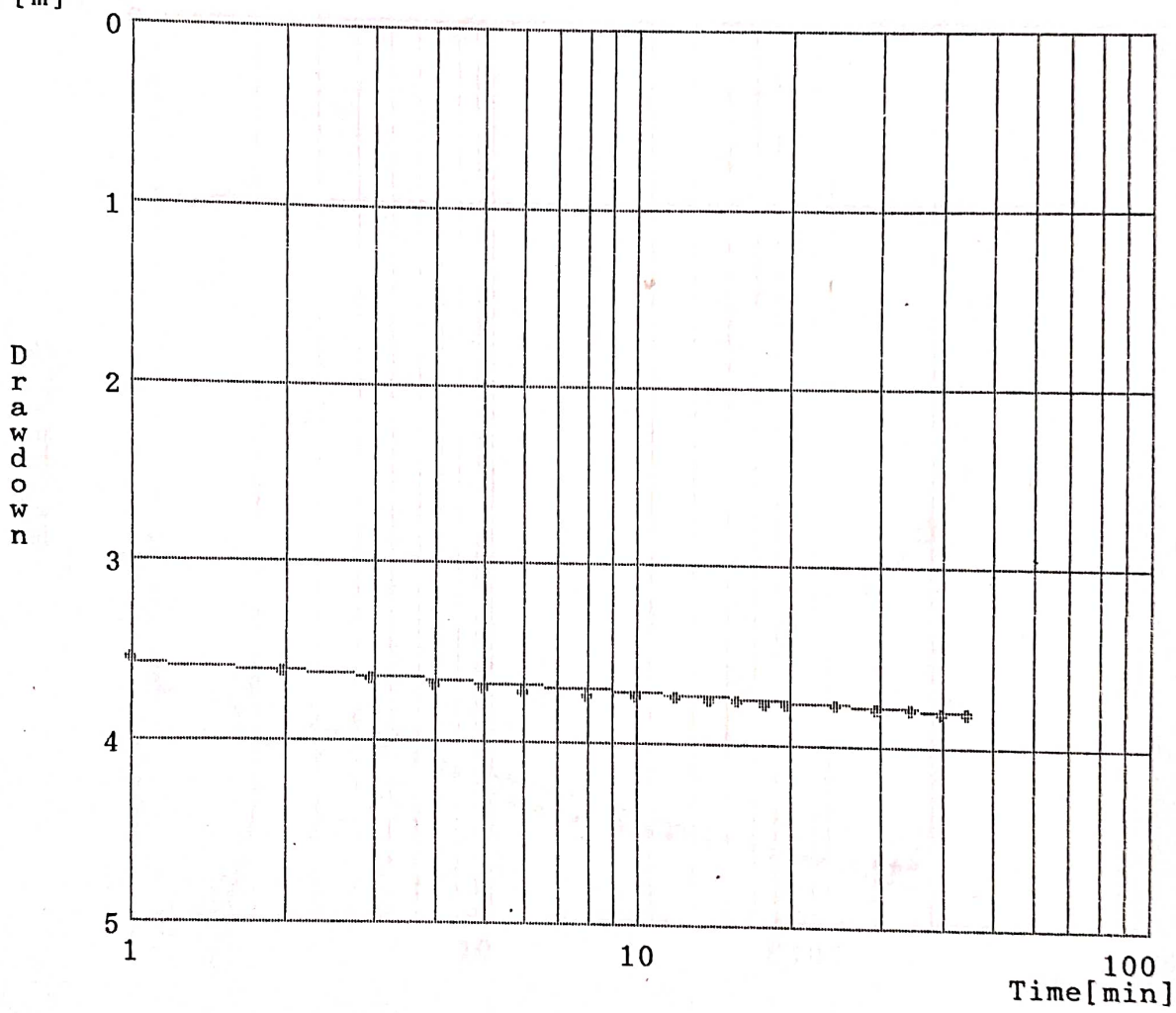
APPENDIX 5/6

Project : UNDP/NEP/86/025
Organization : UNDTCD/GWRDB

Test : UN 10 - BHALWARI

Constant Pumping Rate = 24.000 [l/sec]
Distance from Pumping Well = 0.05 [m]
Type of Aquifer = CONFINED
Type of Input Data = LEVEL
Static Water Level = -0.46 [m]
Well Type = STANDARD

JACOB METHOD



Transmissivity = 2585. [m2/day]

Storage Coefficient = 0.00000000

Standard Deviation = 0.0162 [m]

A0 = 0.356675E+01

A1 = 0.146769E+00

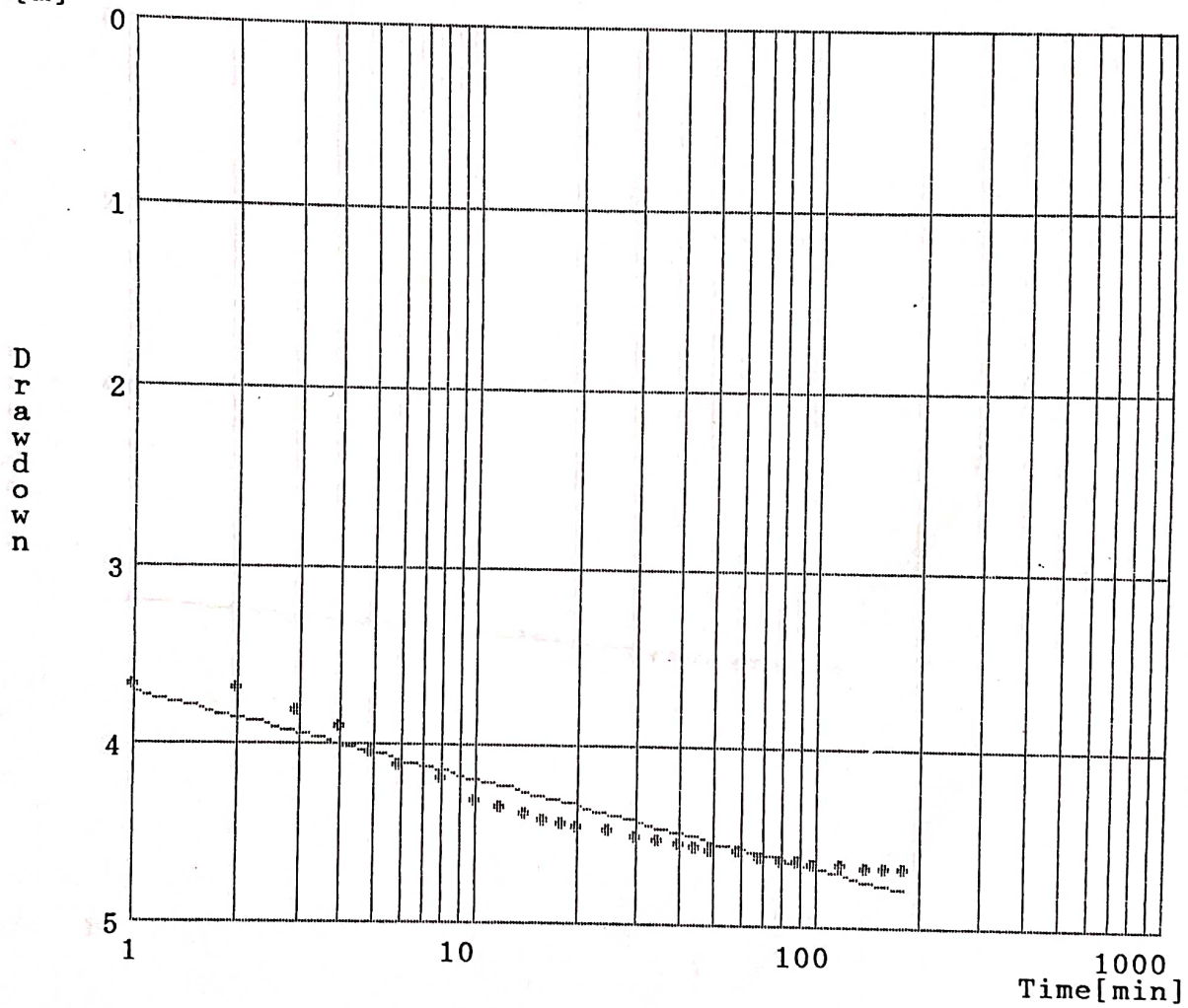
Number of Points = 18 of 18

Project : UNDP/NEP/86/025
Organization : UNDTCD/GWRDB

Test : UN 11 - MAKRAHAR

Constant Pumping Rate = 20.000 [l/sec]
Distance from Pumping Well = 0.05 [m]
Type of Aquifer = CONFINED
Type of Input Data = LEVEL
Static Water Level = -1.55 [m]
Well Type = STANDARD

JACOB METHOD



Transmissivity = 655. [m2/day]

Storage Coefficient = 0.00000883

Standard Deviation = 0.0863 [m]

A0 = 0.370540E+01

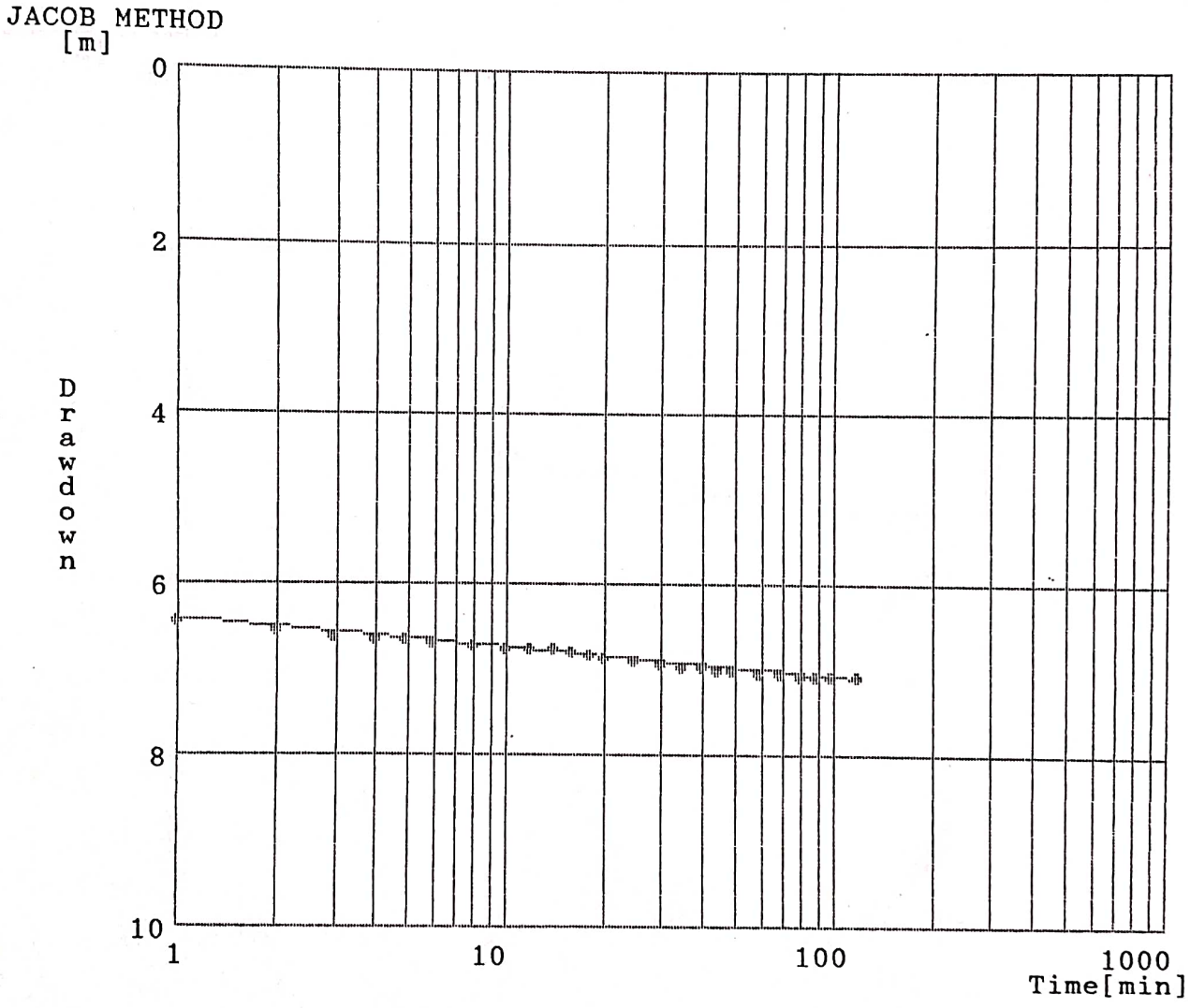
A1 = 0.482795E+00

Number of Points = 28 of 28

Project : UNDP/NEP/86/025
Organization : UNDTCD/GWRDB

Test : UN 12 - PANANI

Constant Pumping Rate = 6.000 [l/sec]
Distance from Pumping Well = 0.05 [m]
Type of Aquifer = CONFINED
Type of Input Data = LEVEL
Static Water Level = 0.78 [m]
Well Type = STANDARD



Transmissivity = 284. [m2/day]

Storage Coefficient = 0.00000000

Standard Deviation = 0.0182 [m]

A0 = 0.640408E+01

A1 = 0.334541E+00

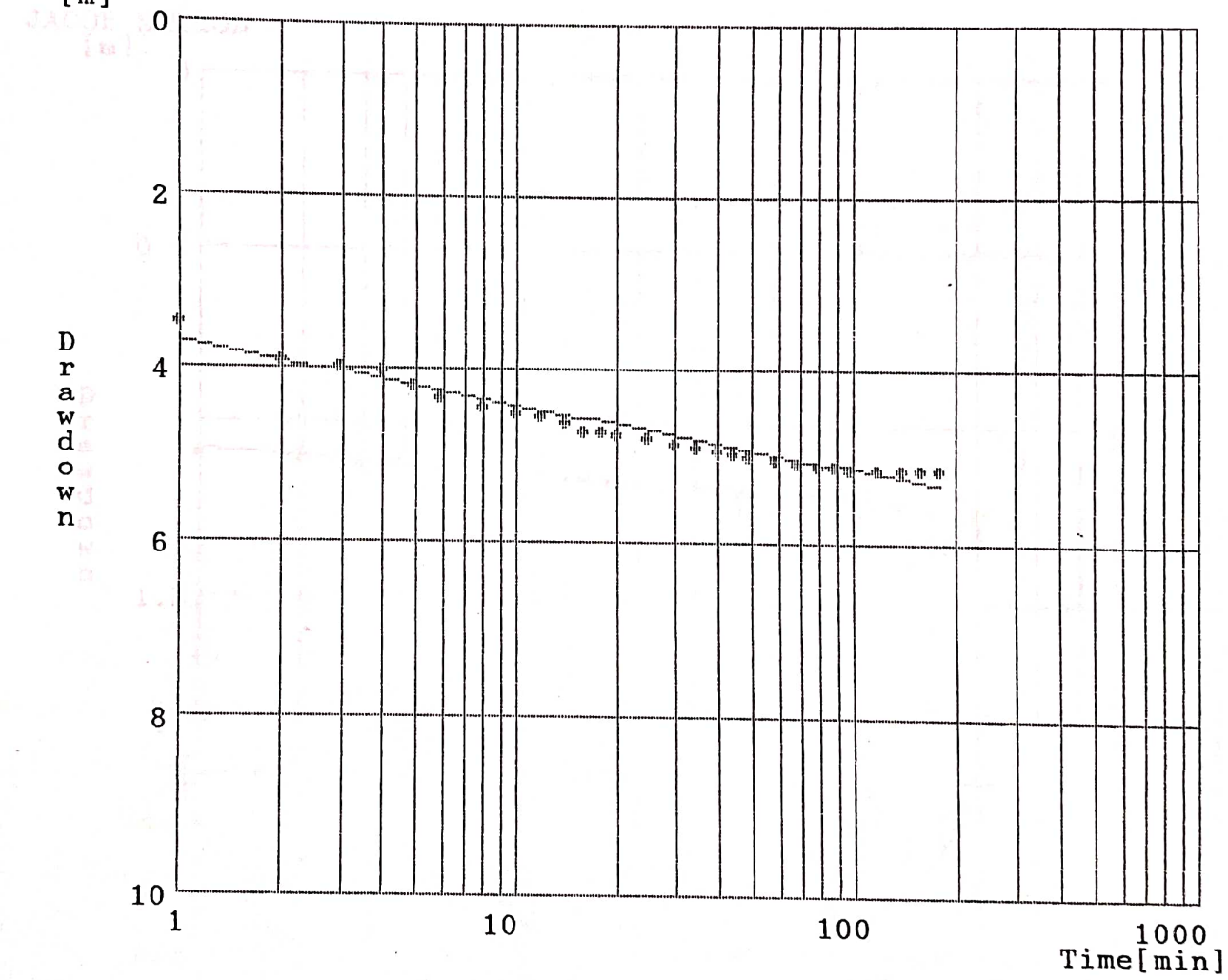
Number of Points = 25 of 25

Project : UNDP/NEP/86/025
Organization : UNDTCD/GWRDB

Test : UN 13 - PARASI JHUNGA

Constant Pumping Rate = 2.000 [l/sec]
Distance from Pumping Well = 0.05 [m]
Type of Aquifer = CONFINED
Type of Input Data = LEVEL
Static Water Level = -3.23 [m]
Well Type = STANDARD

JACOB METHOD



Transmissivity = 43. [m2/day]

Storage Coefficient = 0.00024155

Standard Deviation = 0.0938 [m]

A0 = 0.368352E+01

A1 = 0.728529E+00

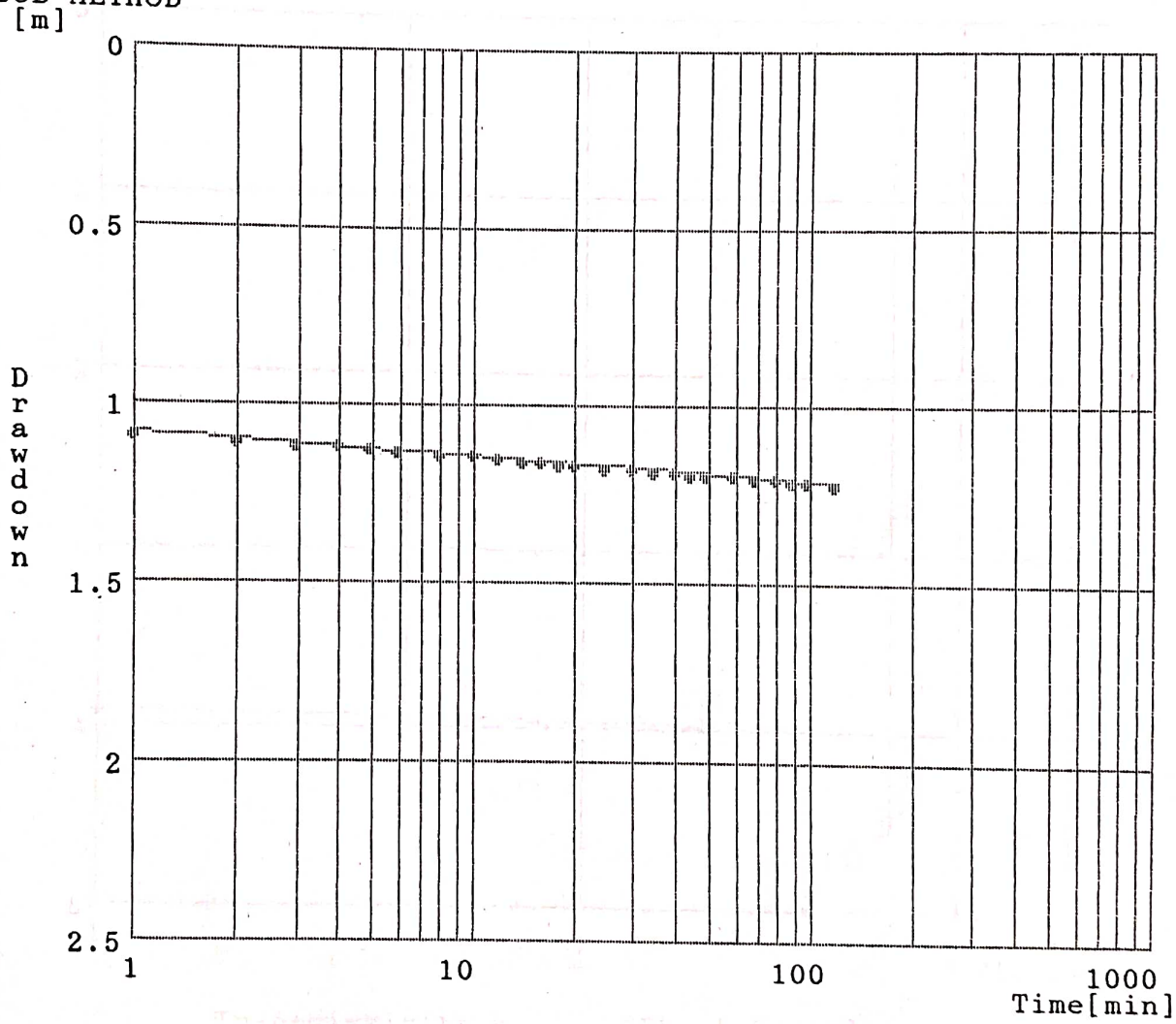
Number of Points = 28 of 28

Project : UNDP/NEP/86/025
Organization : UNDTCD/GWRDB

Test : UN 14 - SIKTHAN

Constant Pumping Rate = 7.500 [l/sec]
Distance from Pumping Well = 0.05 [m]
Type of Aquifer = UNCONFINED
Initial Saturated Thickness = 7.55 [m]
Type of Input Data = LEVEL
Static Water Level = -7.77 [m]
Well Type = STANDARD

JACOB METHOD



Transmissivity = 1817. [m2/day]

Storage Coefficient = 0.00000000

Standard Deviation = 0.0028 [m]

A0 = 0.108002E+01

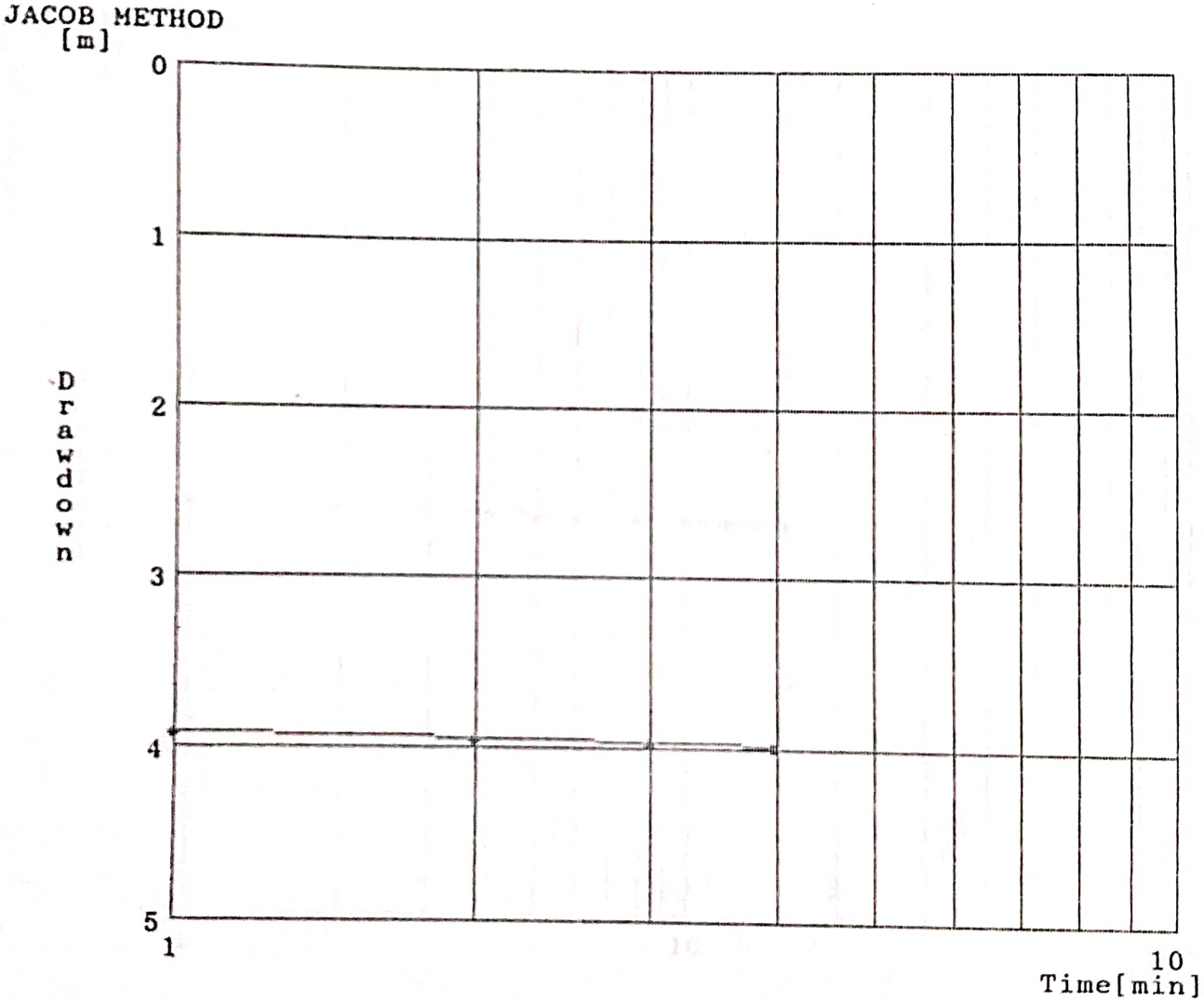
A1 = 0.652668E-01

Number of Points = 25 of 25

Project : UNDP/NEP/86/025
Organization : UNDTCD/GWRDB

Test : UN 22 - SISO SEMARA

Constant Pumping Rate = 1.500 [l/sec]
Distance from Pumping Well = 0.05 [m]
Type of Aquifer = CONFINED
Type of Input Data = LEVEL
Static Water Level = -4.54 [m]
Well Type = STANDARD



Transmissivity = 208. [m2/day]

Storage Coefficient = 0.00000000

Standard Deviation = 0.0026 [m]

A0 = 0.390823E+01

A1 = 0.113808E+00

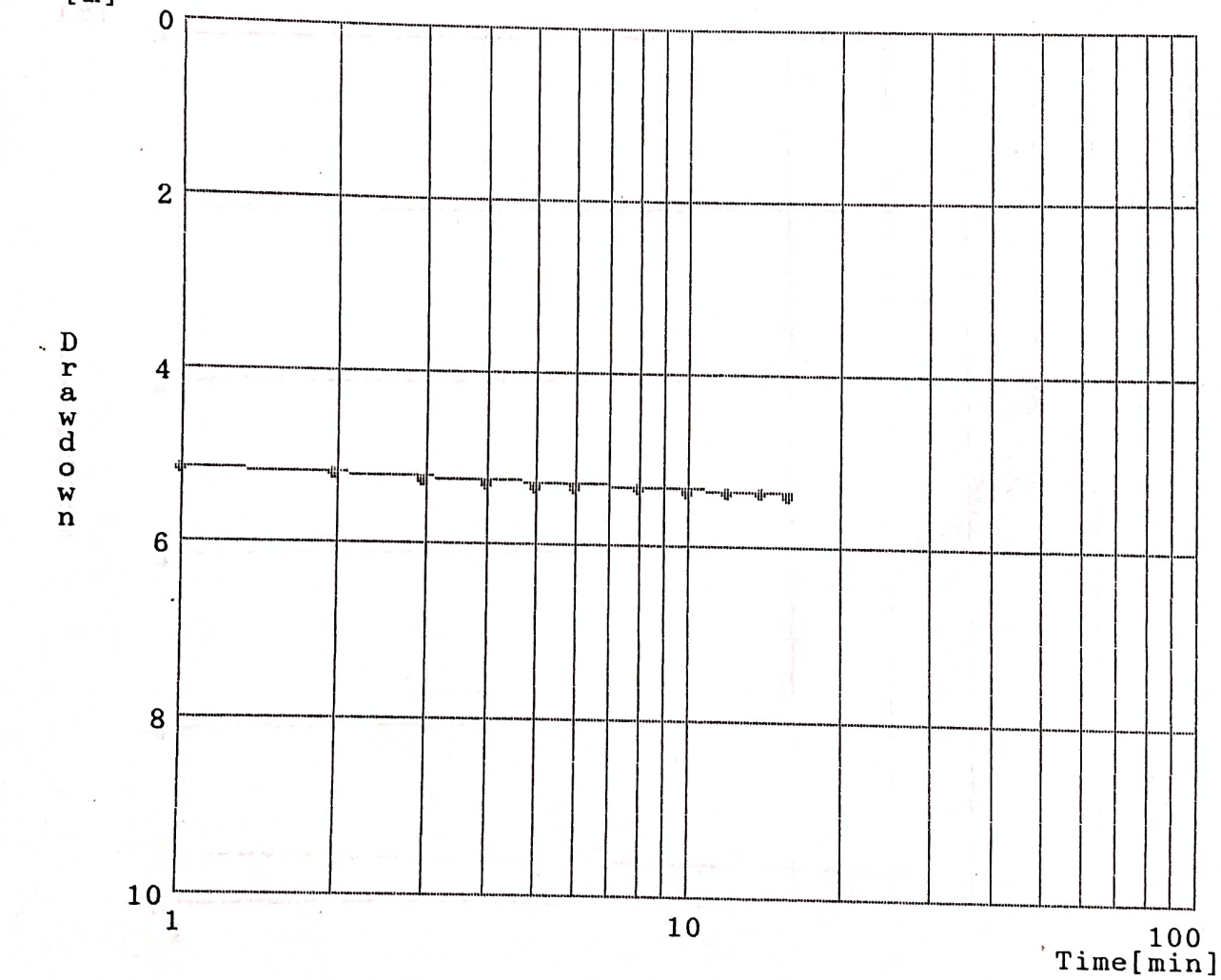
Number of Points = 4 of 4

Project : UNDP/NEP/86/025
Organization : UNDTCD/GWRDB

Test : UN 23 - RAMNAGAR

Constant Pumping Rate = 7.500 [l/sec]
Distance from Pumping Well = 0.05 [m]
Type of Aquifer = CONFINED
Type of Input Data = LEVEL
Static Water Level = -3.58 [m]
Well Type = STANDARD

JACOB METHOD



Transmissivity = 592. [m2/day]

Storage Coefficient = 0.00000000

Standard Deviation = 0.0146 [m]

A0 = 0.513267E+01

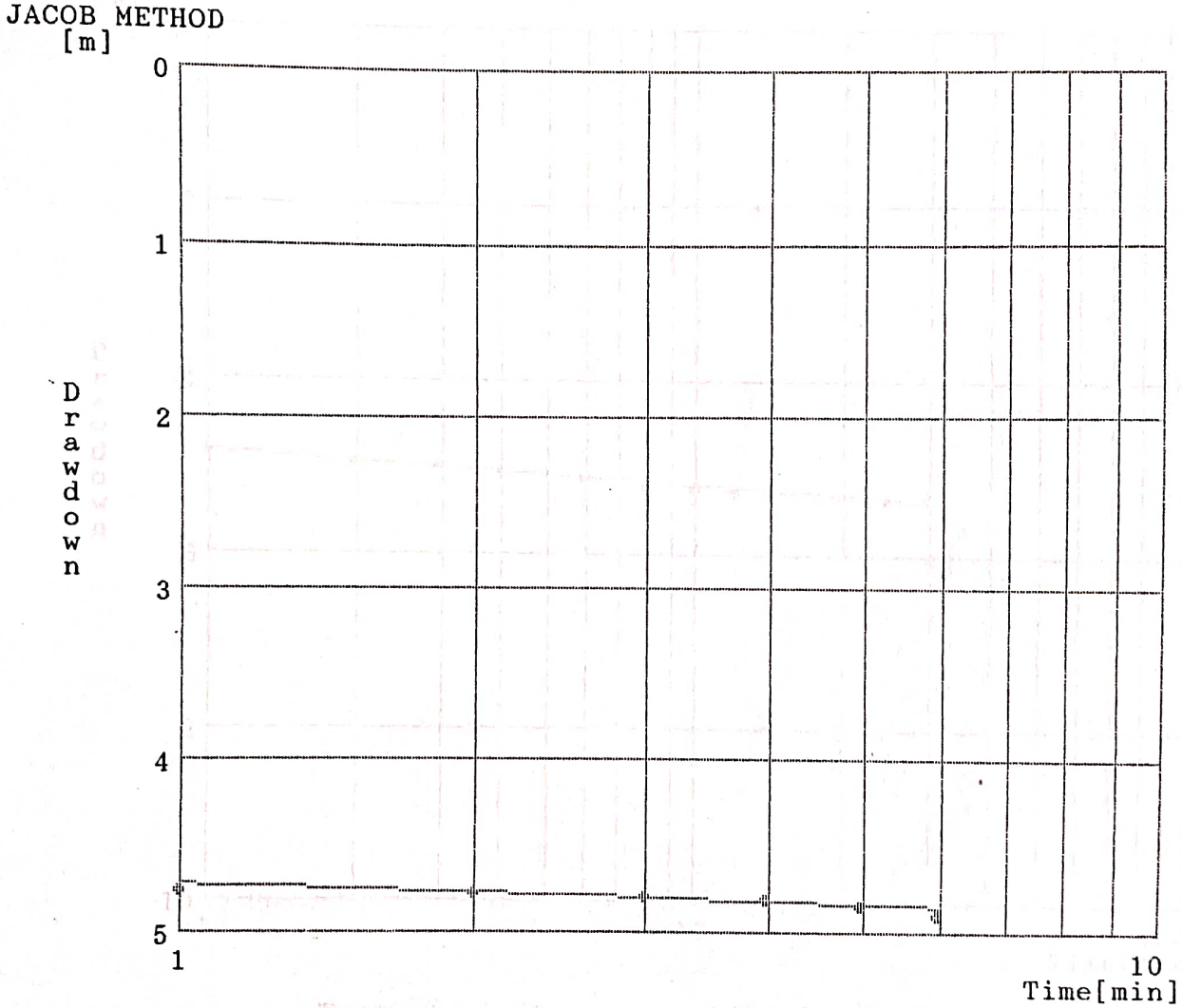
A1 = 0.200329E+00

Number of Points = 11 of 11

Project : UNDP/NEP/86/025
Organization : UNDTCD/GWRDB

Test : UN 24 - BOGARI

Constant Pumping Rate = 1.500 [l/sec]
Distance from Pumping Well = 0.05 [m]
Type of Aquifer = CONFINED
Type of Input Data = LEVEL
Static Water Level = -4.06 [m]
Well Type = STANDARD



Transmissivity = 141. [m2/day]

Storage Coefficient = 0.00000000

Standard Deviation = 0.0222 [m]

A0 = 0.472017E+01

A1 = 0.167641E+00

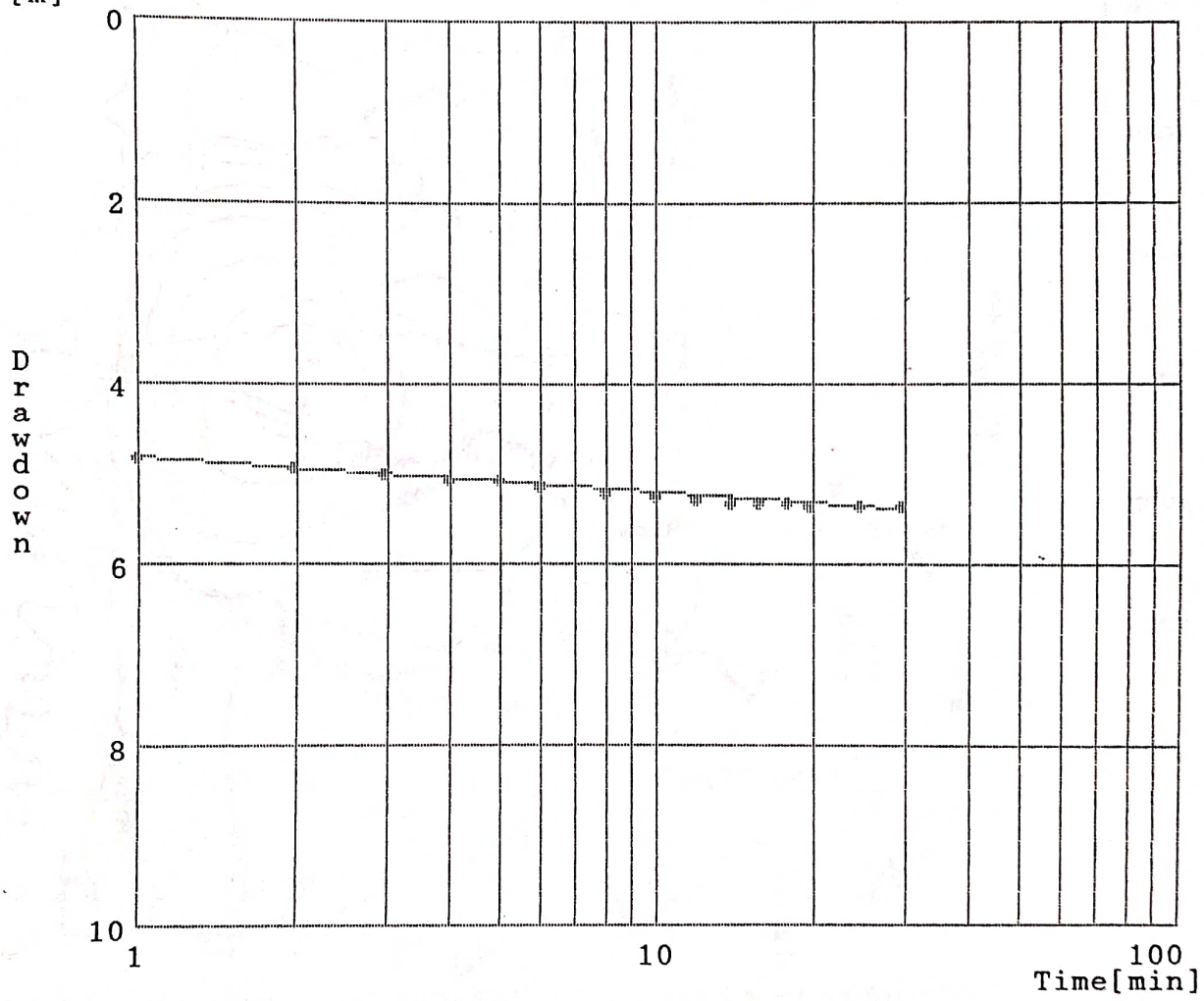
Number of Points = 6 of 6

Project : UNDP/NEP/86/025
Organization : UNDTCD/GWRDB

Test : UN 25 - BICHAWAPUR

Constant Pumping Rate = 3.500 [l/sec]
Distance from Pumping Well = 0.05 [m]
Type of Aquifer = CONFINED
Type of Input Data = LEVEL
Static Water Level = -2.45 [m]
Well Type = STANDARD

JACOB METHOD



Transmissivity = 142. [m2/day]

Storage Coefficient = 0.00000000

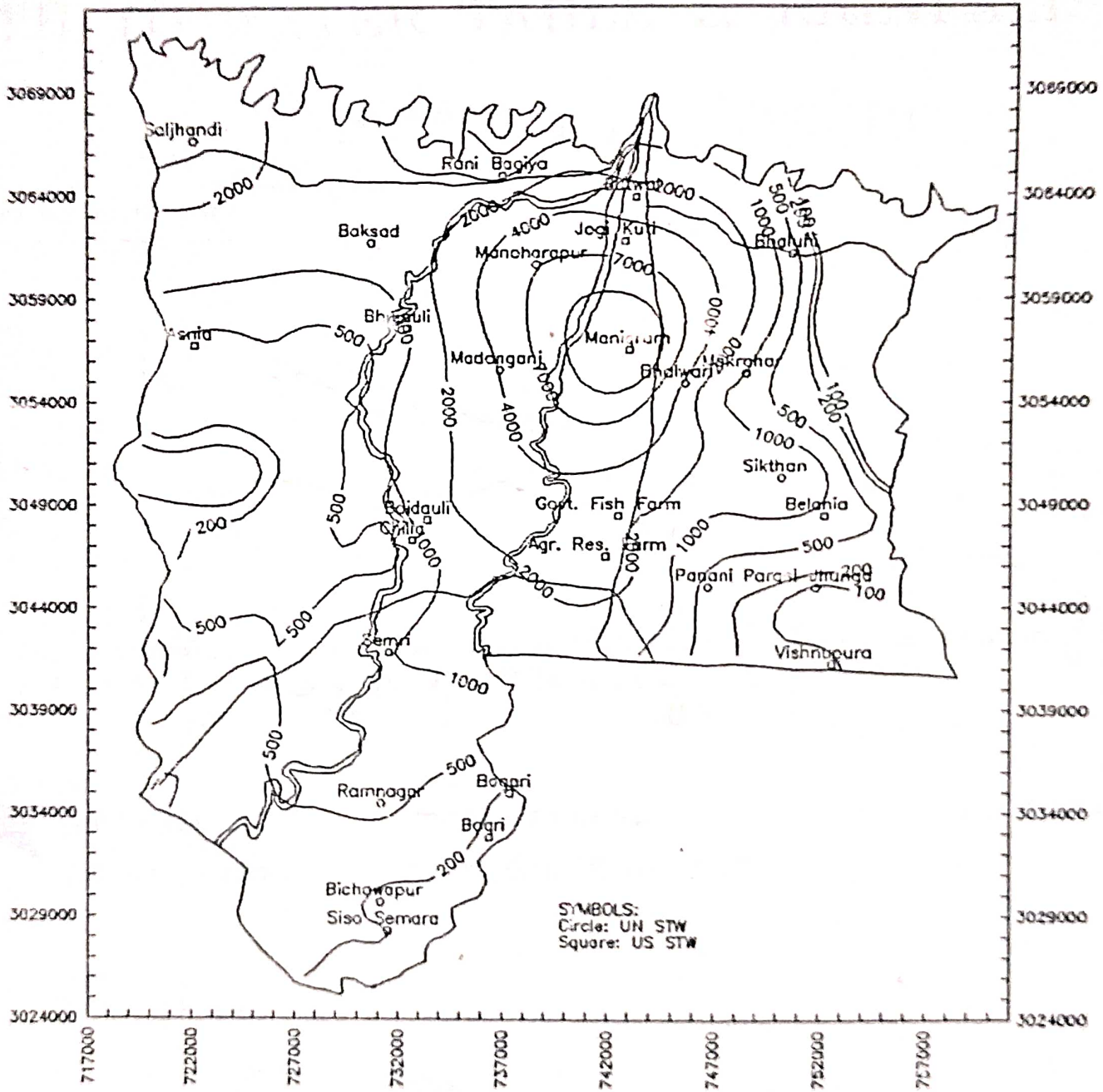
Standard Deviation = 0.0196 [m]

A0 = 0.481919E+01

A1 = 0.390360E+00

Number of Points = 15 of 15

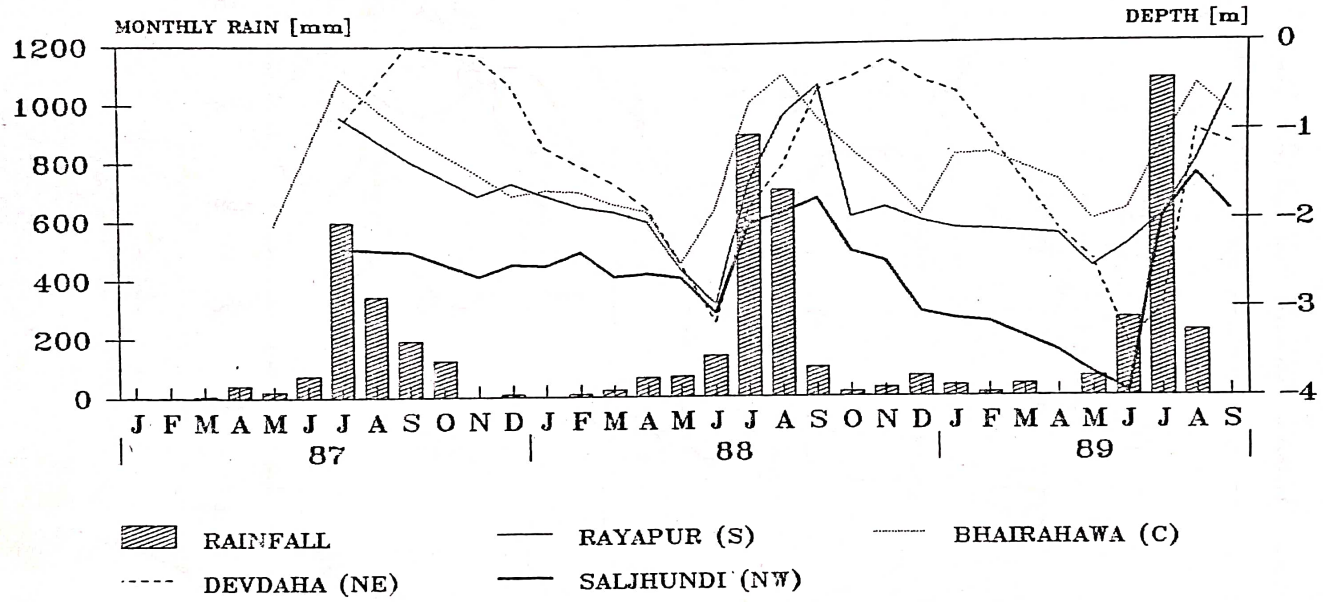
RUPANDEHI – TRANSMISSIVITIES (M2/DAY)



APPENDIX 6

DEPTH TO WATER TABLE & RAINFALL 1987–89

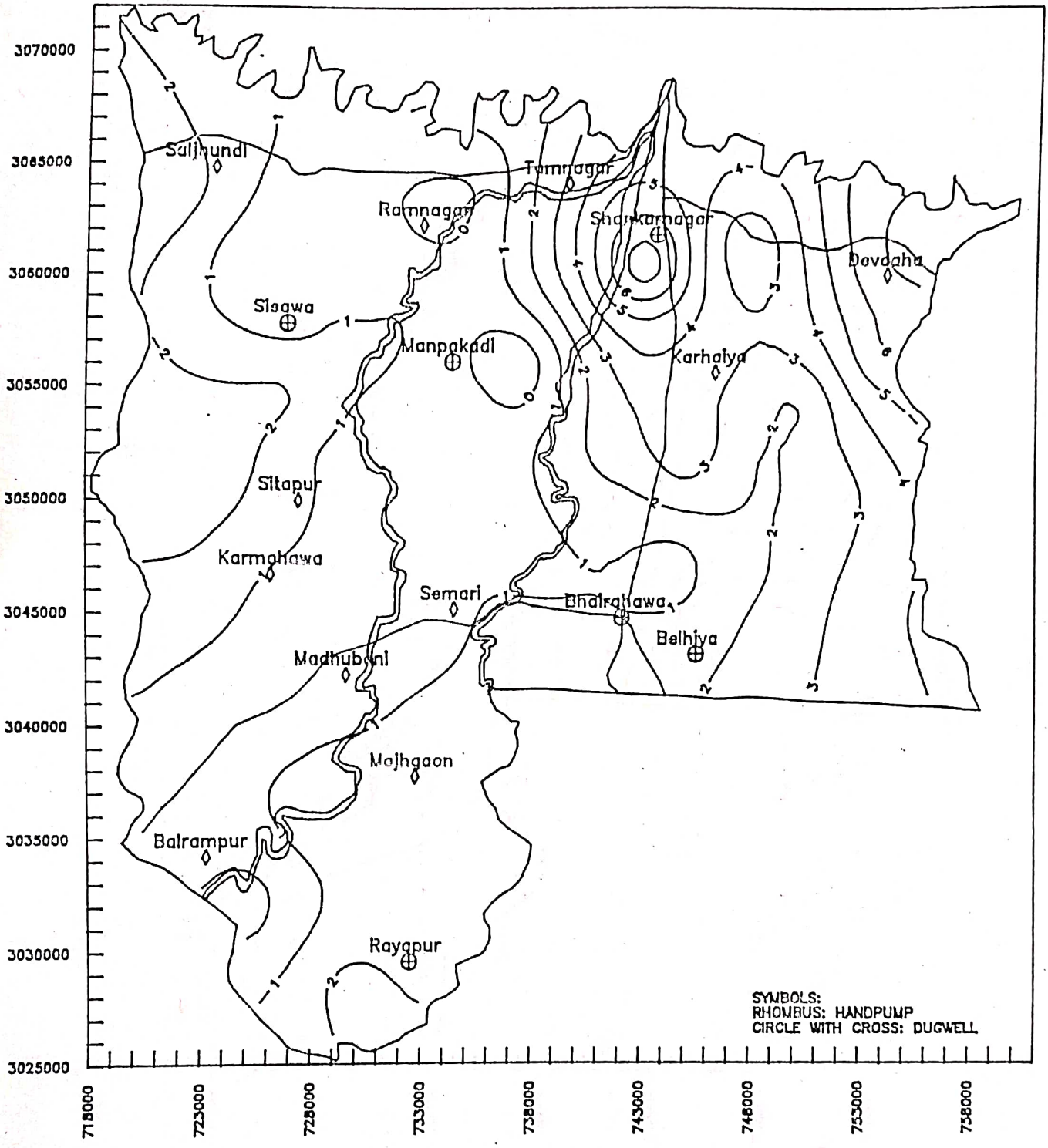
DISTRICT RUPANDEHI



Total Rainfall at Bhairahawa
1987: 1408 mm
1988: 2115 mm

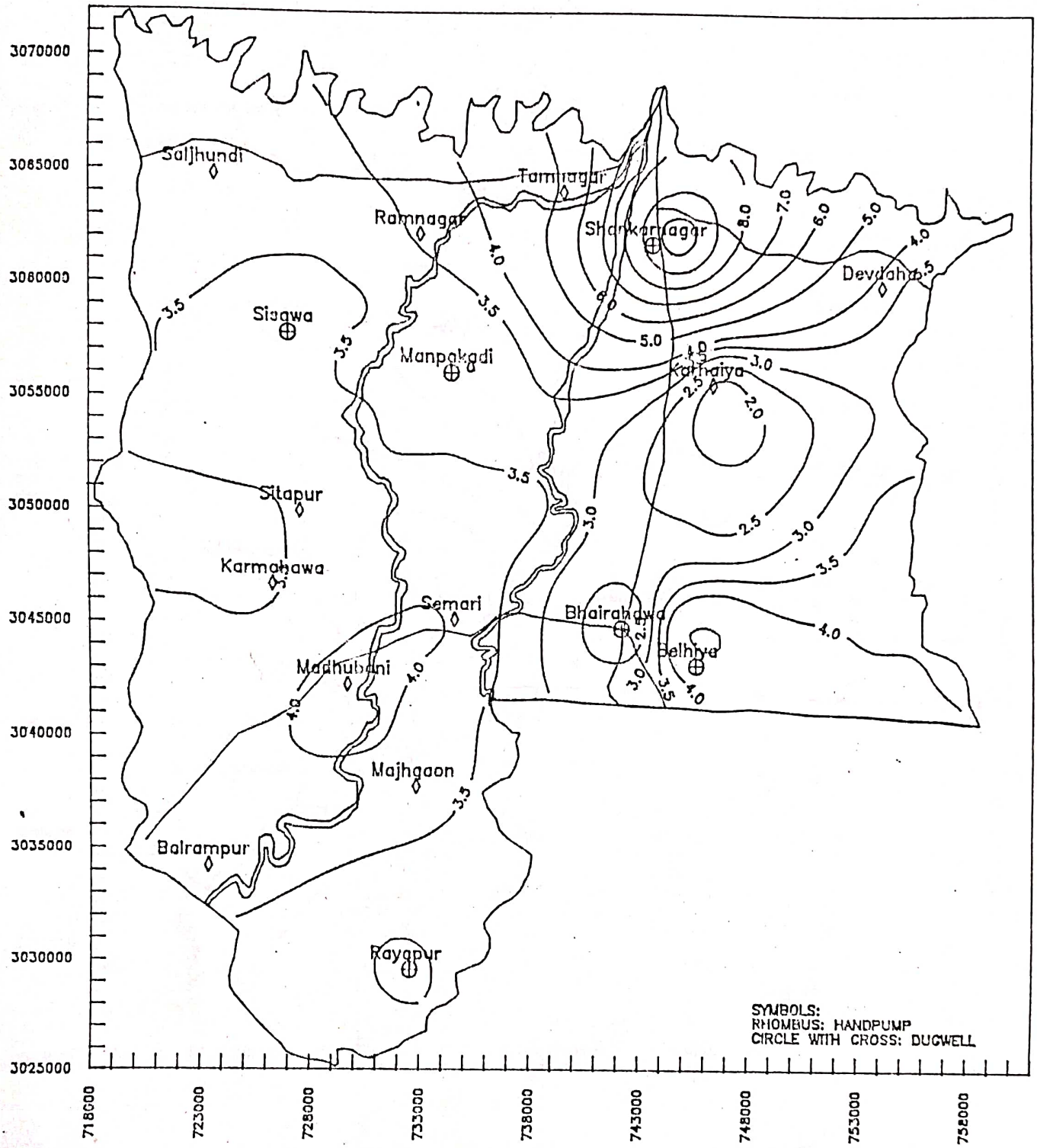
APPENDIX 7

RUPANDEHI RISE OF WATER TABLE MAY – SEP 1987



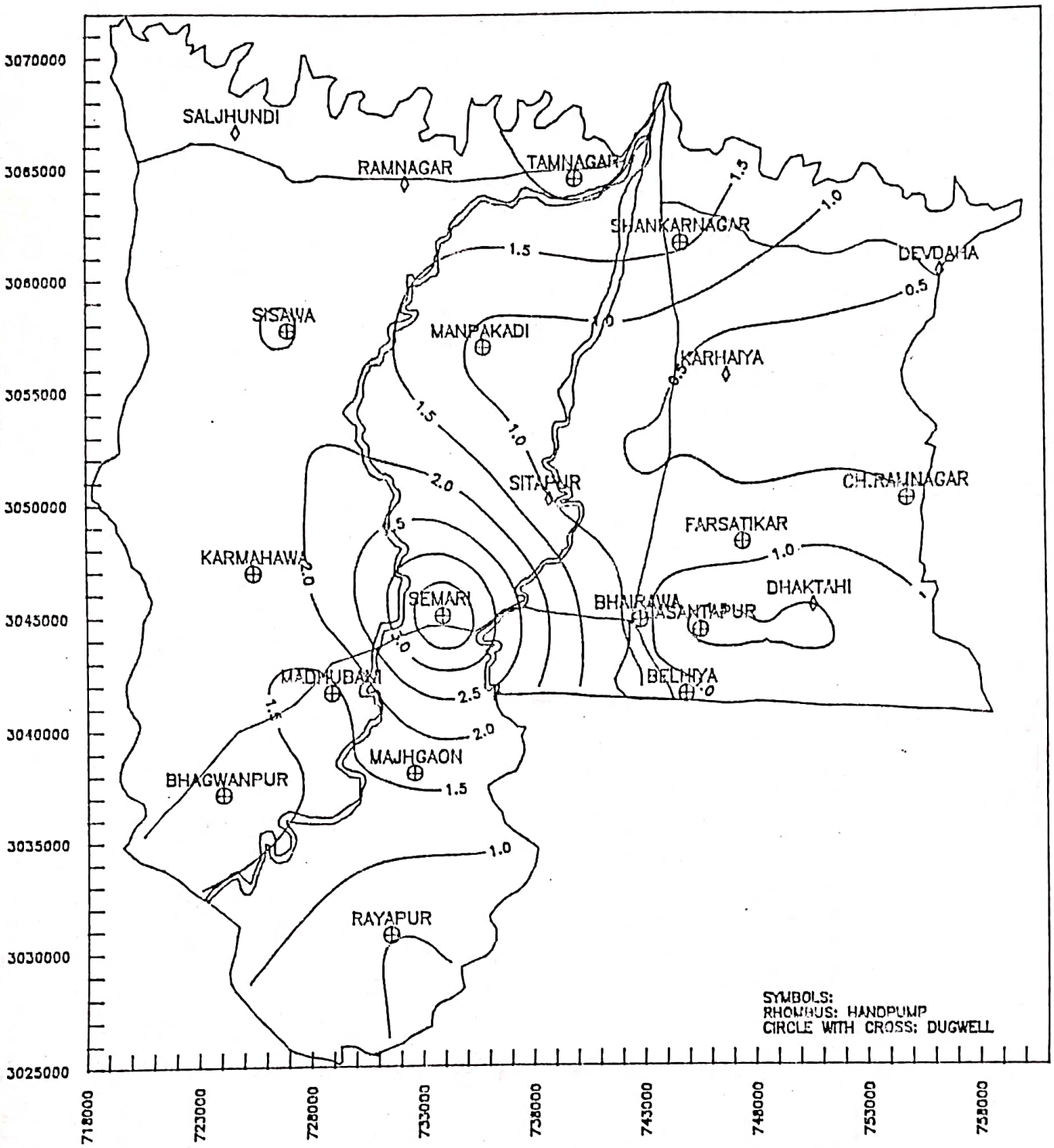
APPENDIX 8/1

RUPANDEHI DEPTH TO WATER TABLE IN JUNE 1988



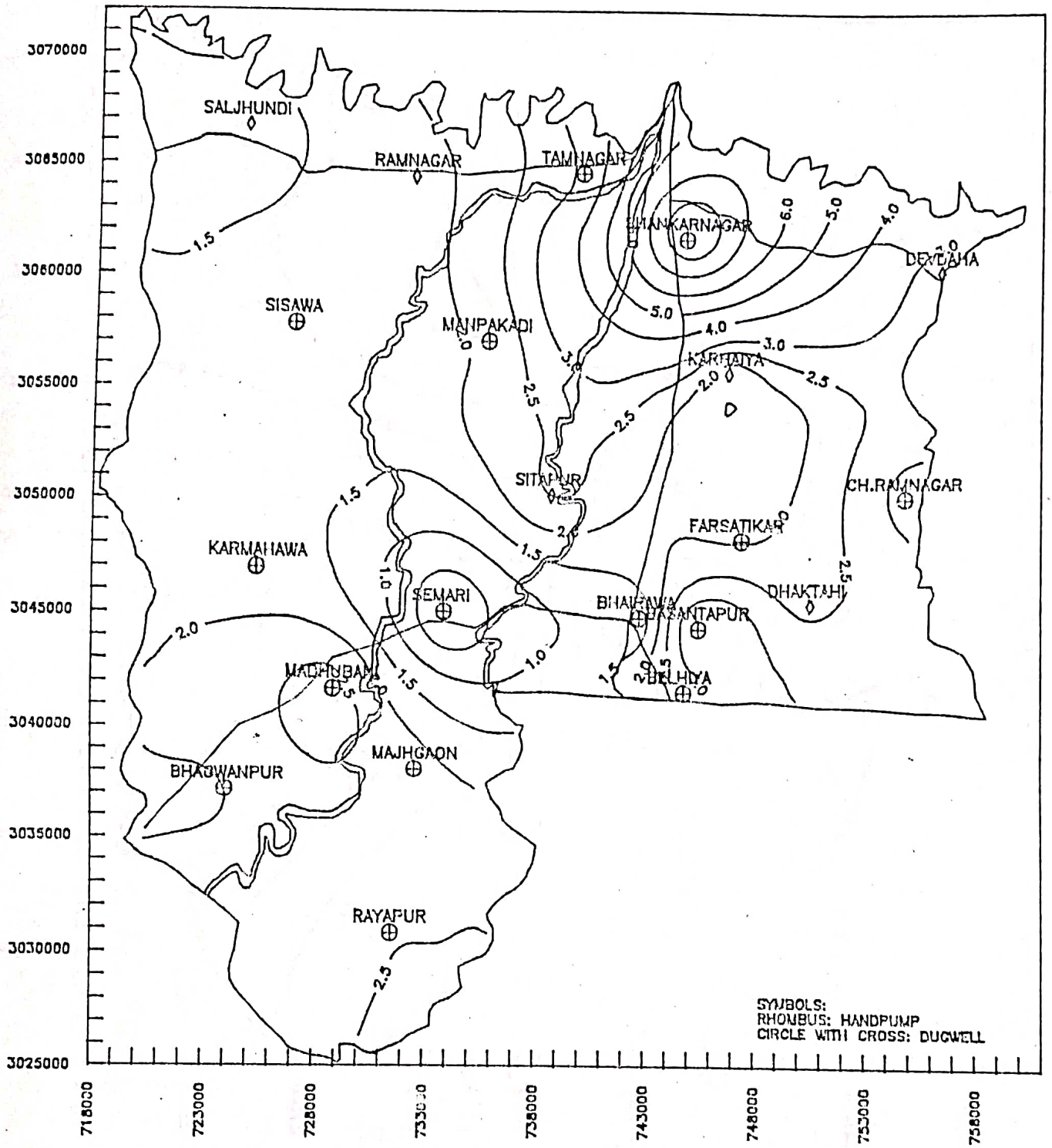
APPENDIX 8/2

RUPANDEHI DEPTH TO WATER TABLE IN SEP 1988



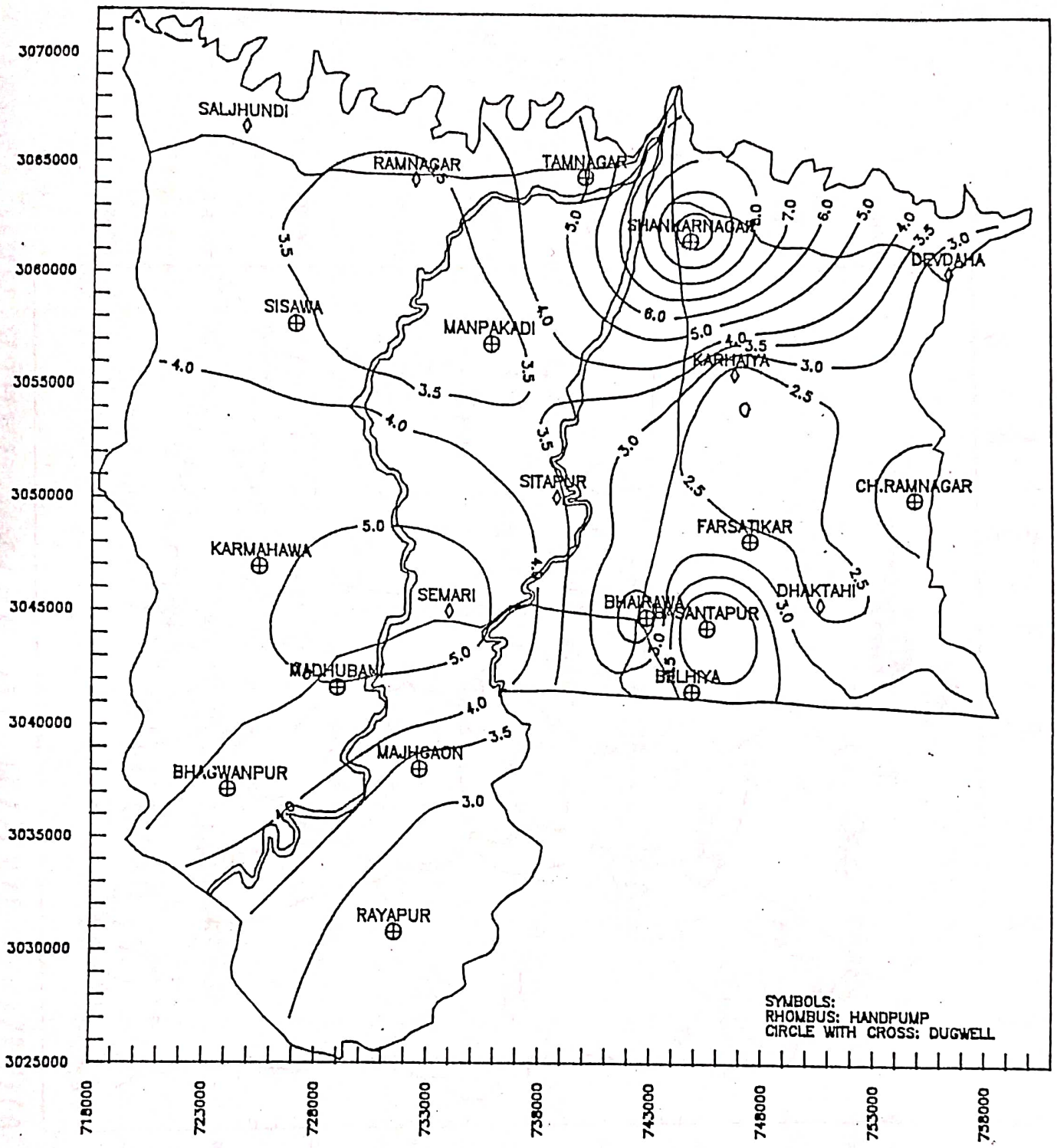
APPENDIX 8/3

RUPANDEHI RISE OF WATER TABLE JUNE – SEP 1988



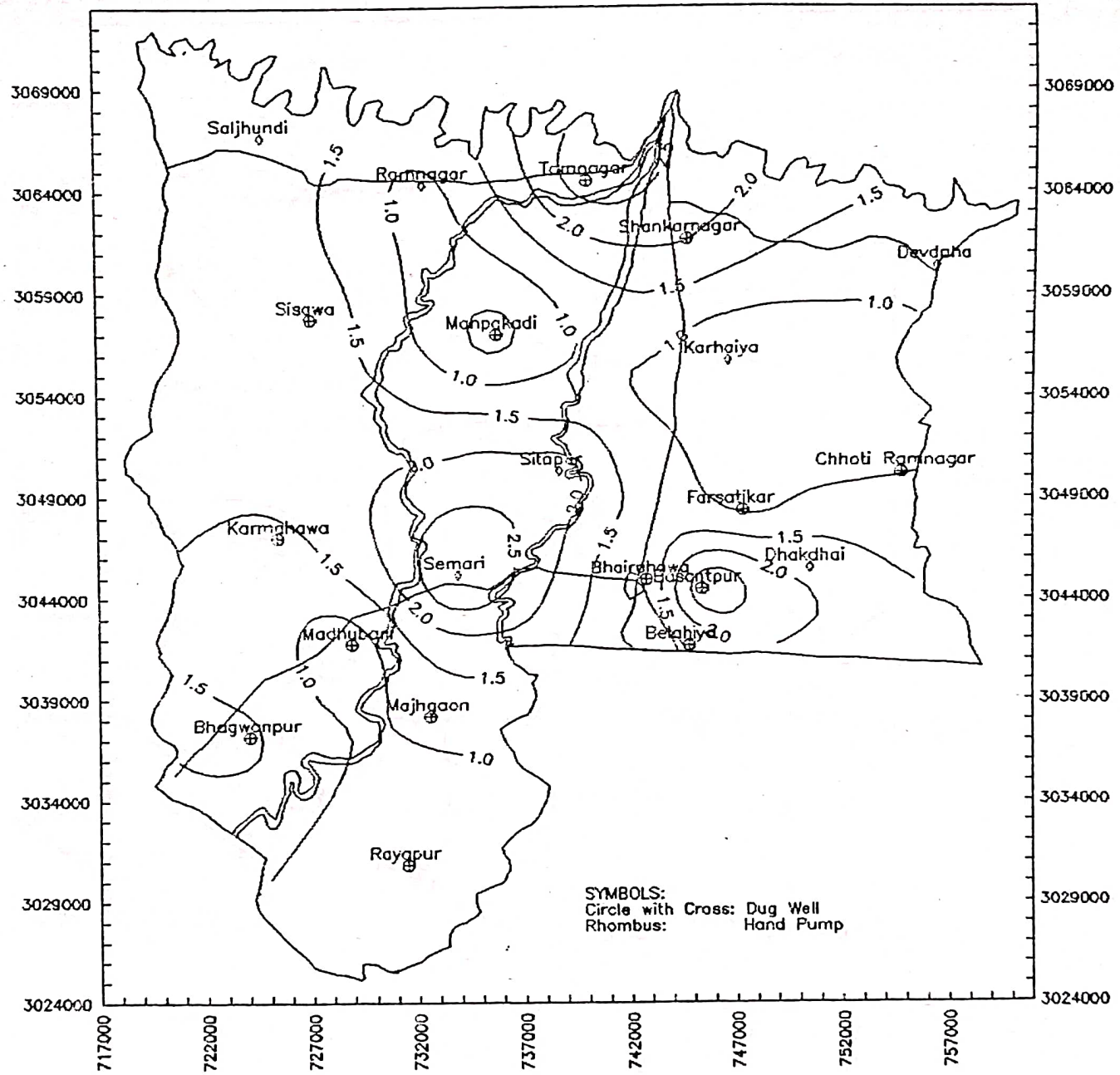
APPENDIX 8/4

RUPANDEHI DEPTH TO WATER TABLE IN MAY 1989



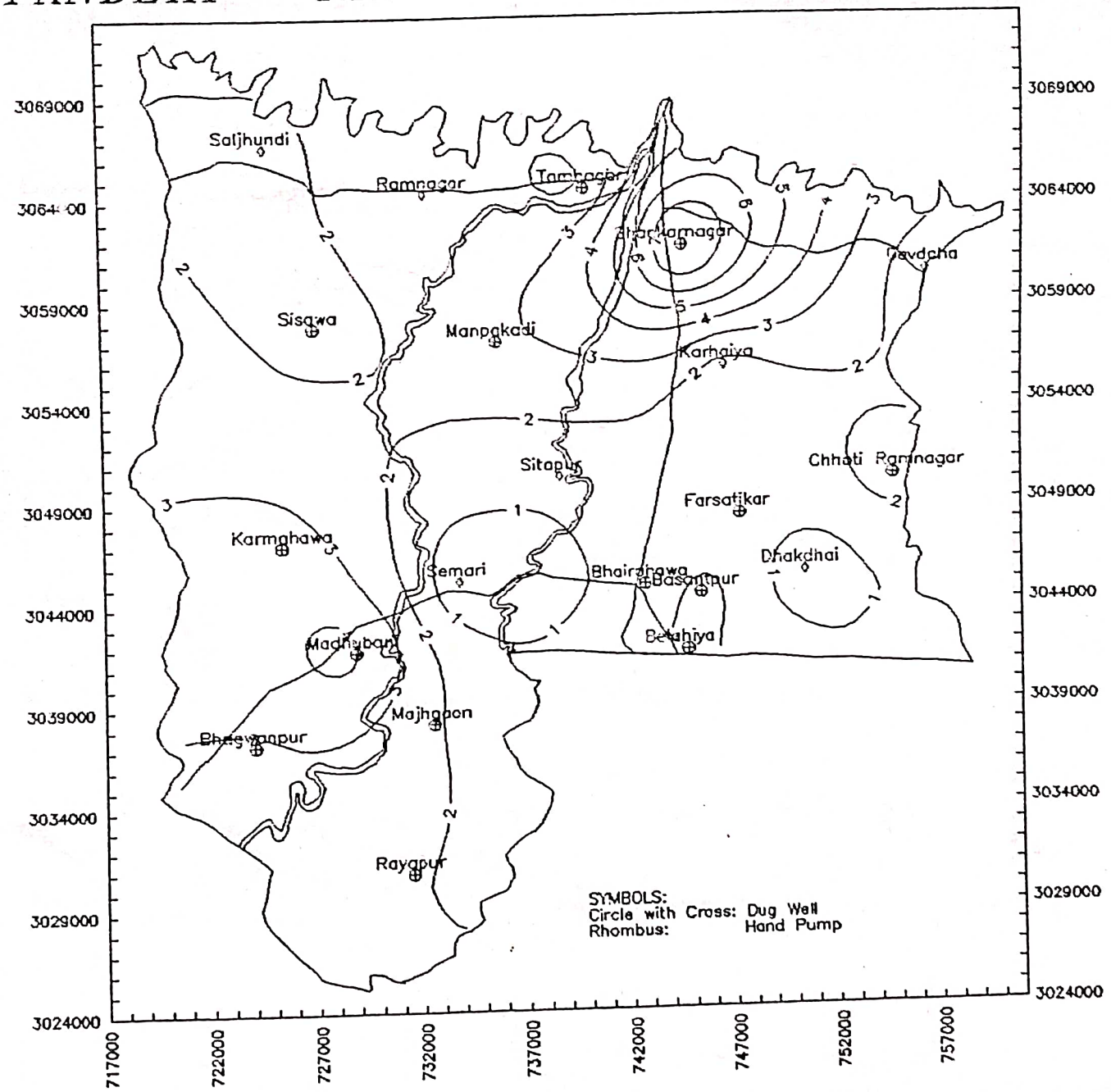
APPENDIX 8/5

RUPANDEHI – DEPTH TO WATER TABLE SEP 1989



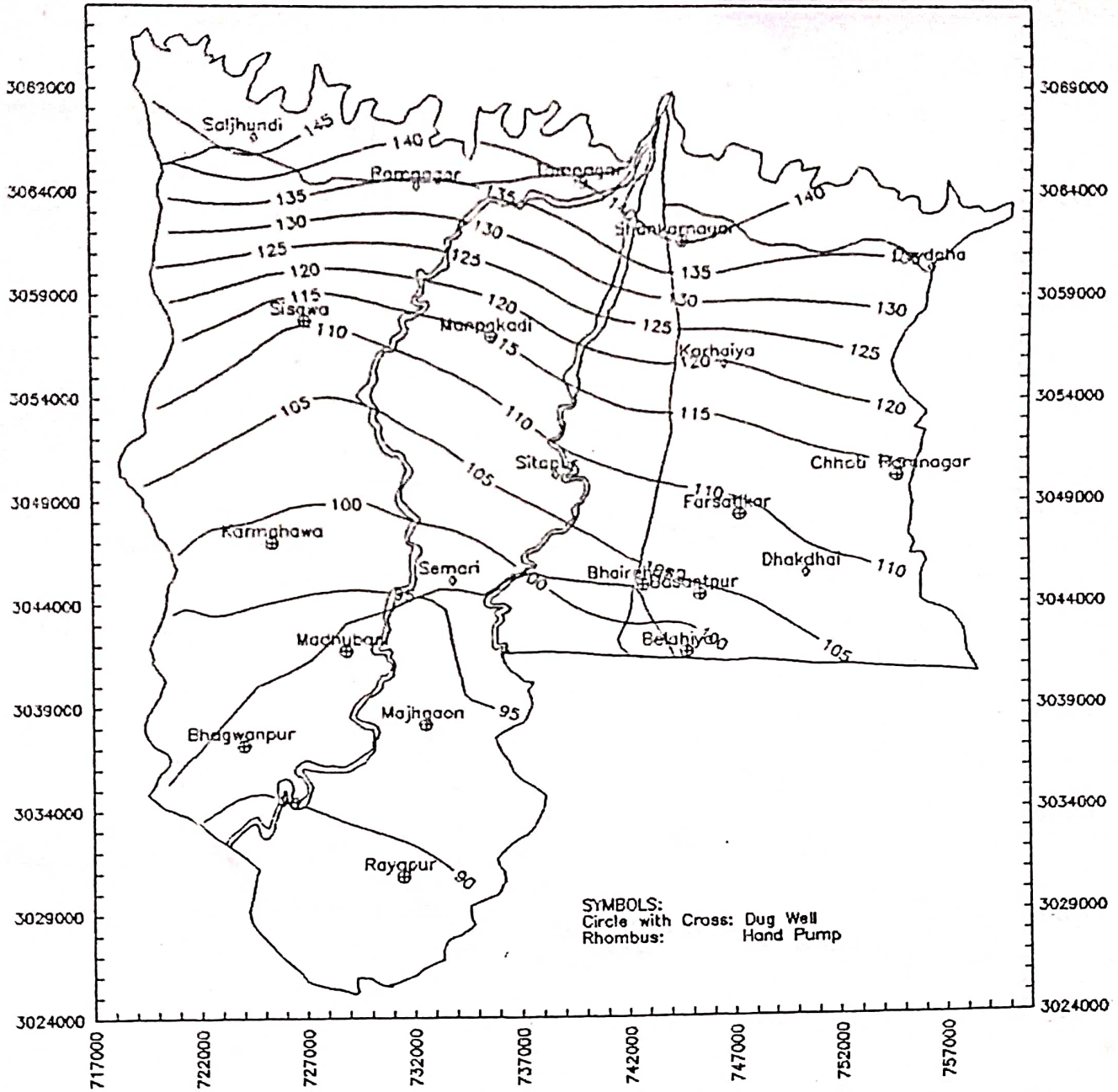
APPENDIX 8/6

RUPANDEHI – RISE OF WATER TABLE MAY–SEP'89

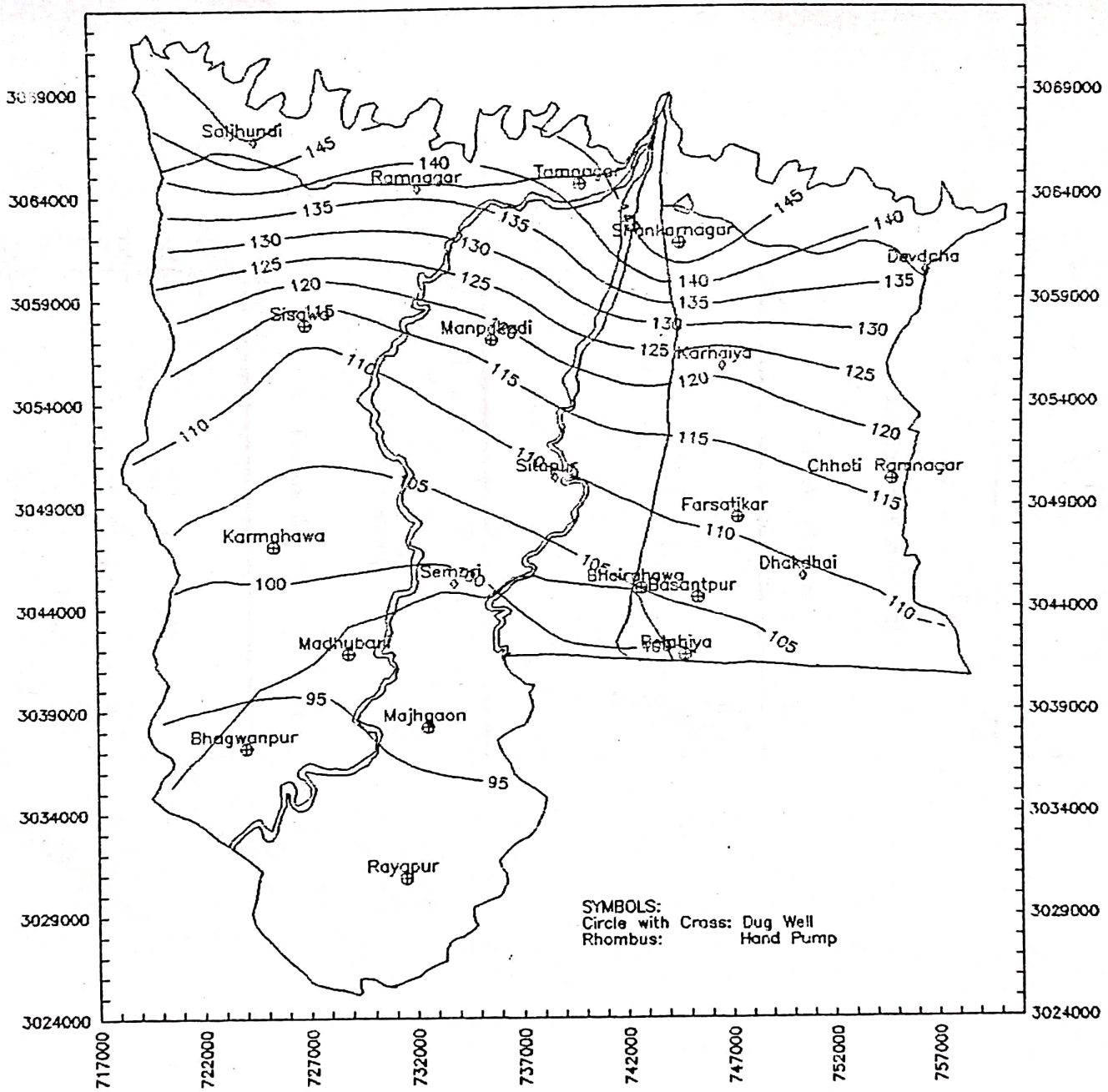


APPENDIX 8/7

RUPANDEHI – WATER LEVEL CONTOUR MAY 1989



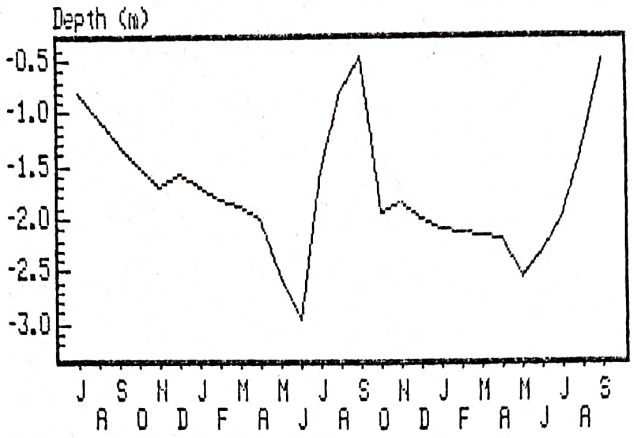
RUPANDEHI – WATER LEVEL CONTOUR SEP 1989



APPENDIX 8/9

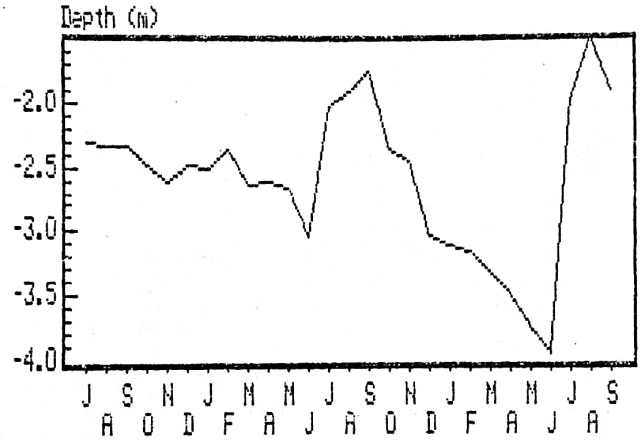
HYDROGRAPHS

Rayapur Dug Well



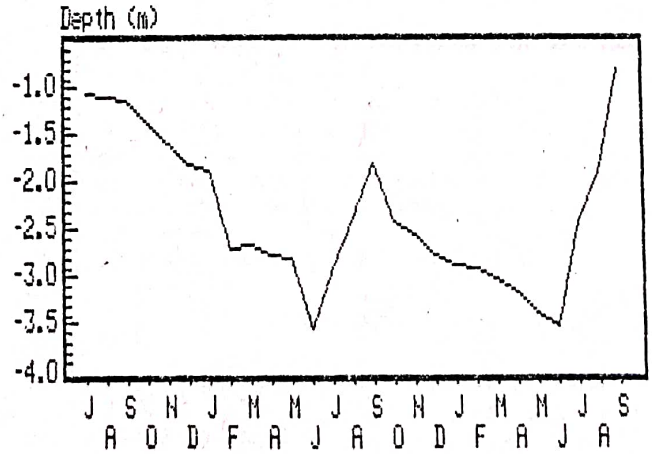
July 1987 - September 1989

Saljhundi Hand Pump



July 1987 - September 1989

Ramnagar Hand Pump

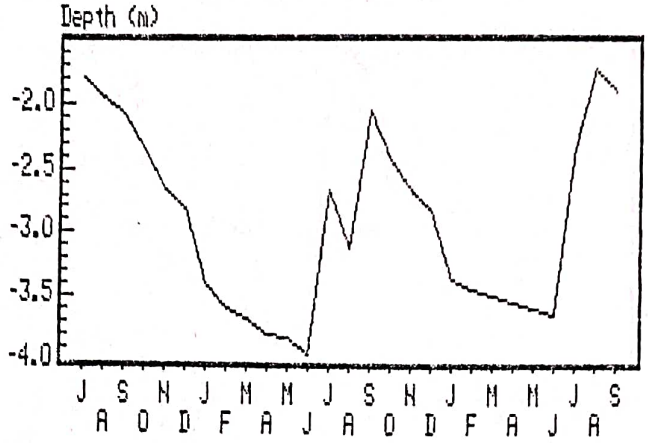


July 1987 - September 1989

APPENDIX 9/1

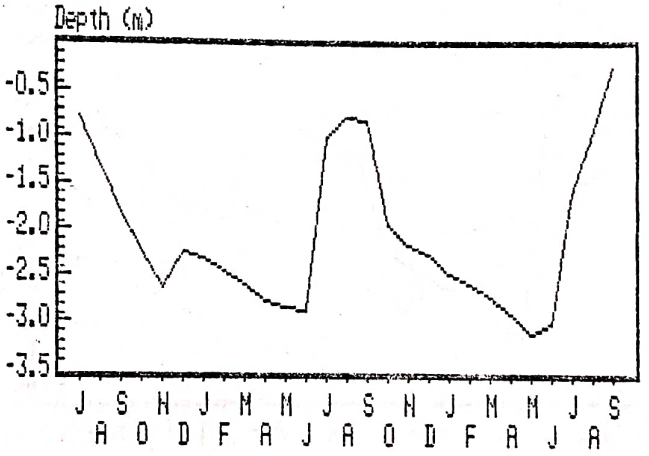
HYDROGRAPHS

Sisawa Dug Well



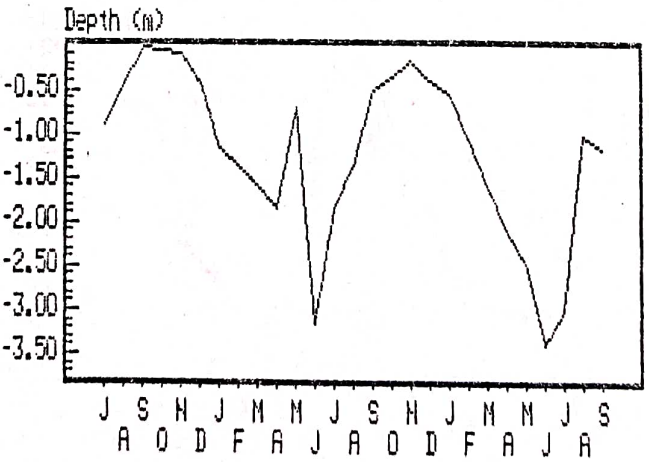
July 1987 - September 1989

Manpakadi Dug Well



July 1987 - September 1989

Devdaha Hand Pump

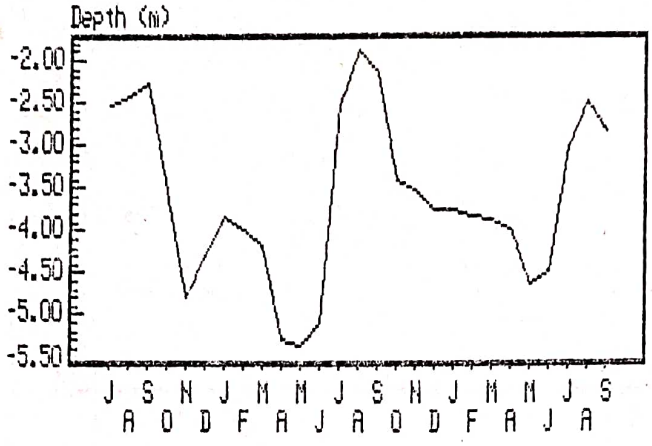


July 1987 - September 1989

APPENDIX 9/2

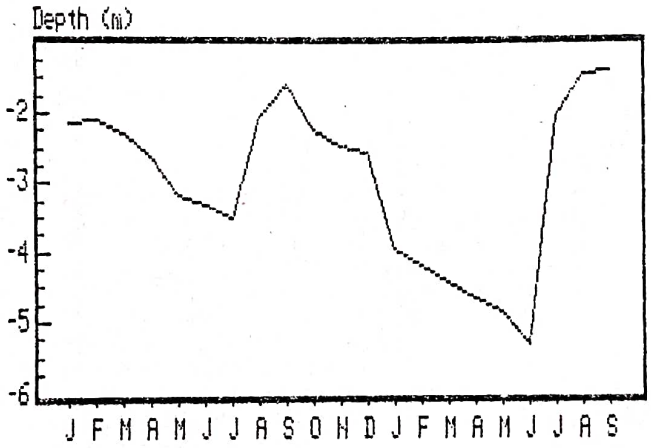
HYDROGRAPHS

Tamnagar Dug Well



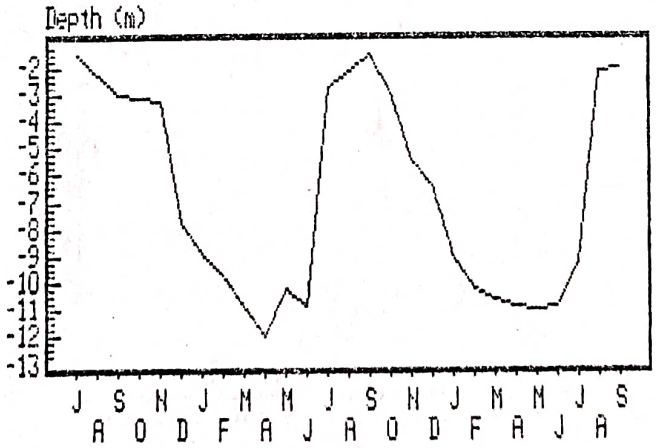
July 1987 - September 1989

Karmahawa Dug Well



January 1988 - September 1989

Shankarnagar Dug Well

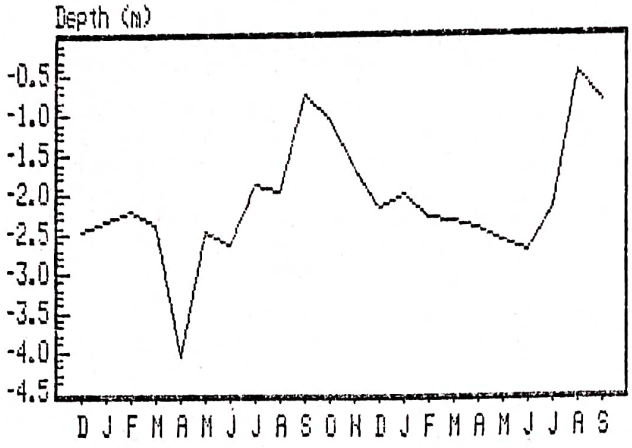


July 1987 - September 1989

APPENDIX 9/3

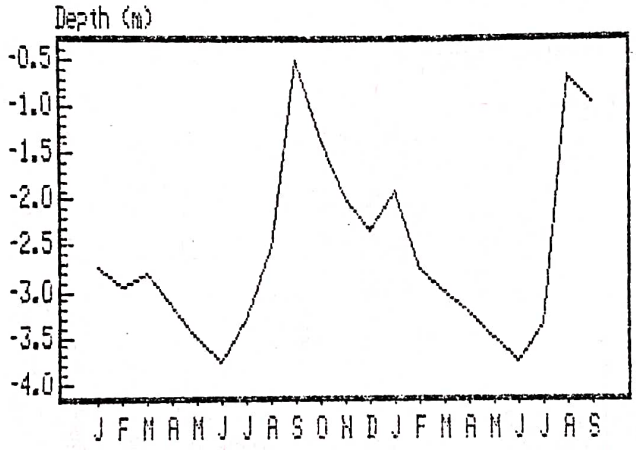
HYDROGRAPHS

Farsatikar Dug Well



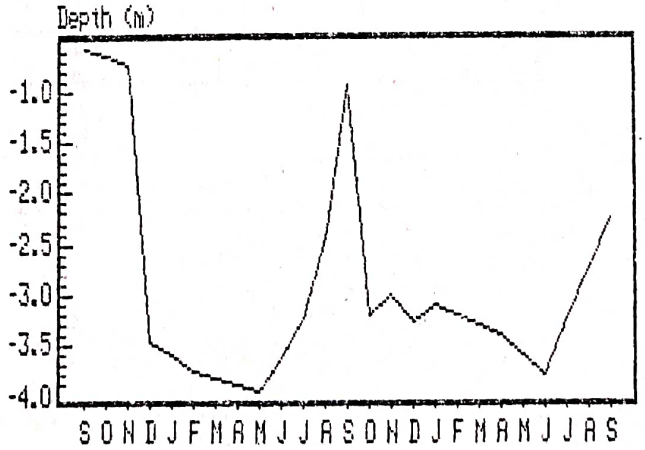
December 1987 - September 1989

Chhoti Ramnagar Dug Well



January 1988 - September 1989

Sitapur Hand Pump

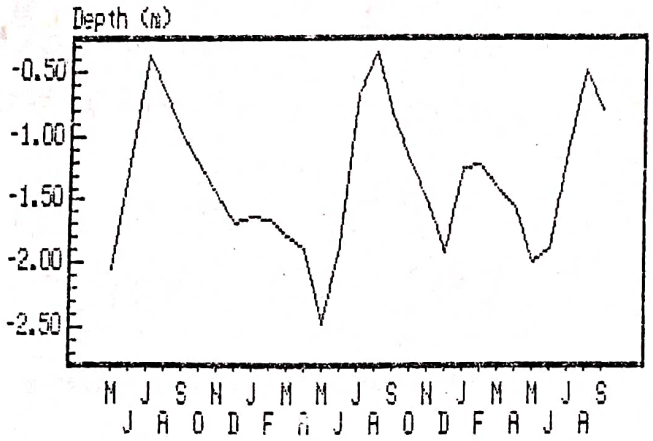


September 1987 - September 1989

APPENDIX 9/4

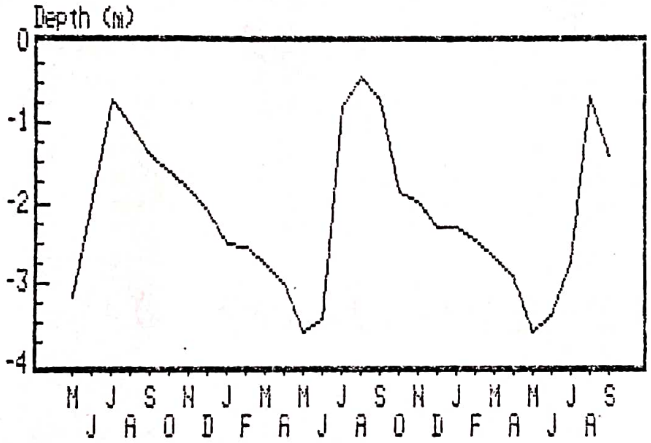
HYDROGRAPHS

Bhairahawa Dug Well

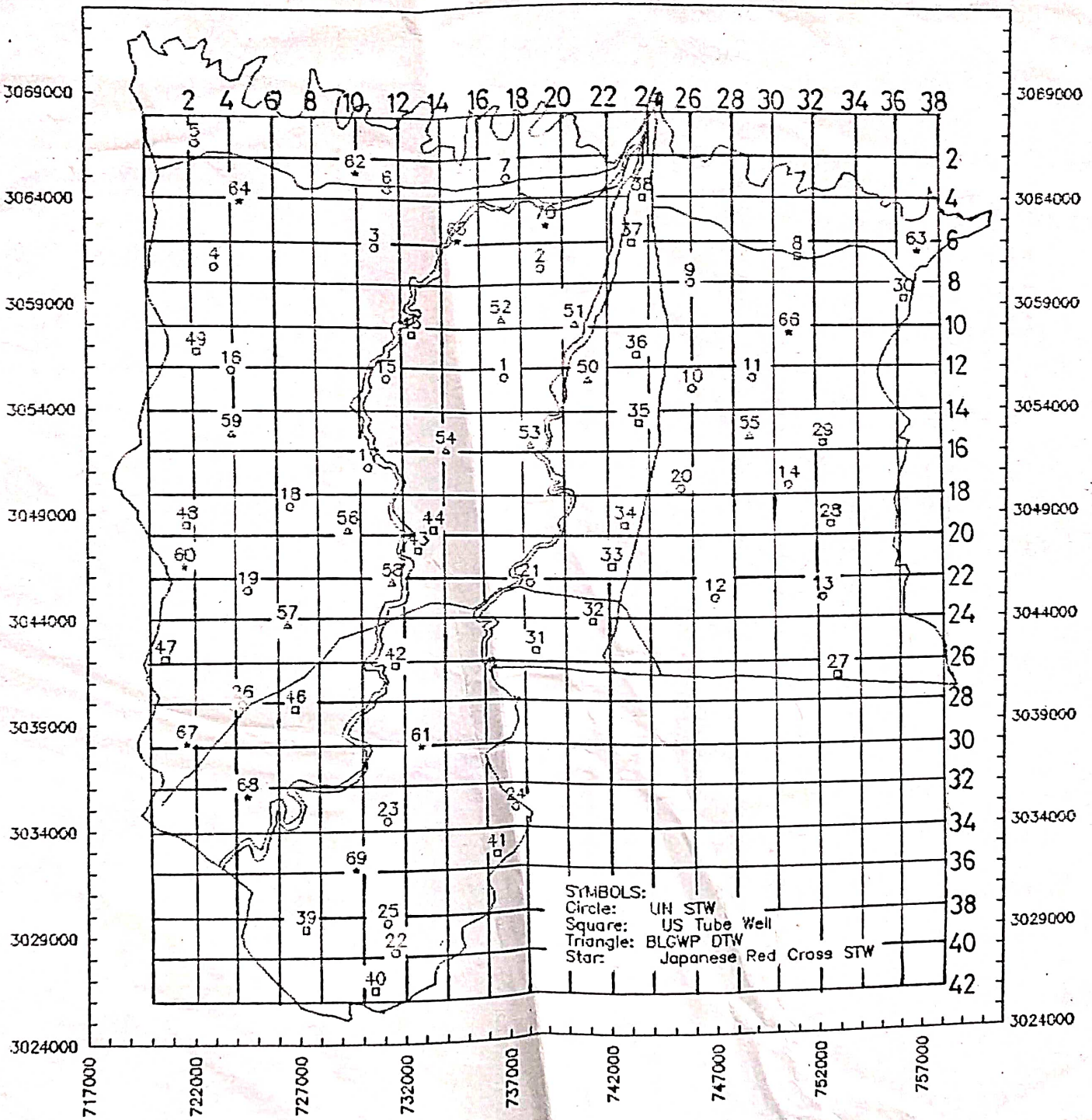


May 1987 - September 1989

Belhiya Dug Well



May 1987 - September 1989

APPENDIX 10

MATHEMATICAL MODEL NETWORK