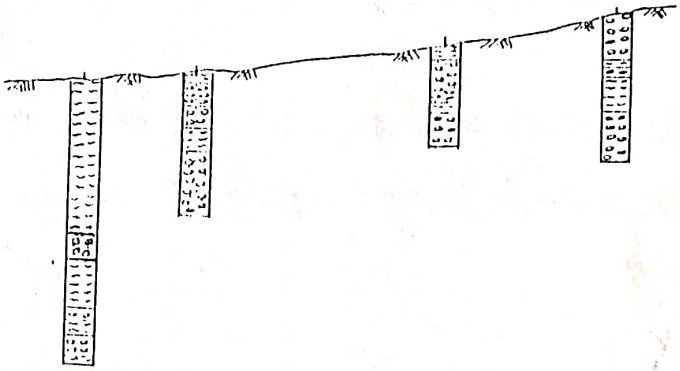
UNITED NATIONS DEVELOPMENT PROGRAMME
AND
HIS MAJESTY's GOVERNMENT OF NEPAL
NEP/86/025

SHALLOW GROUND WATER INVESTIGATIONS IN TERAI

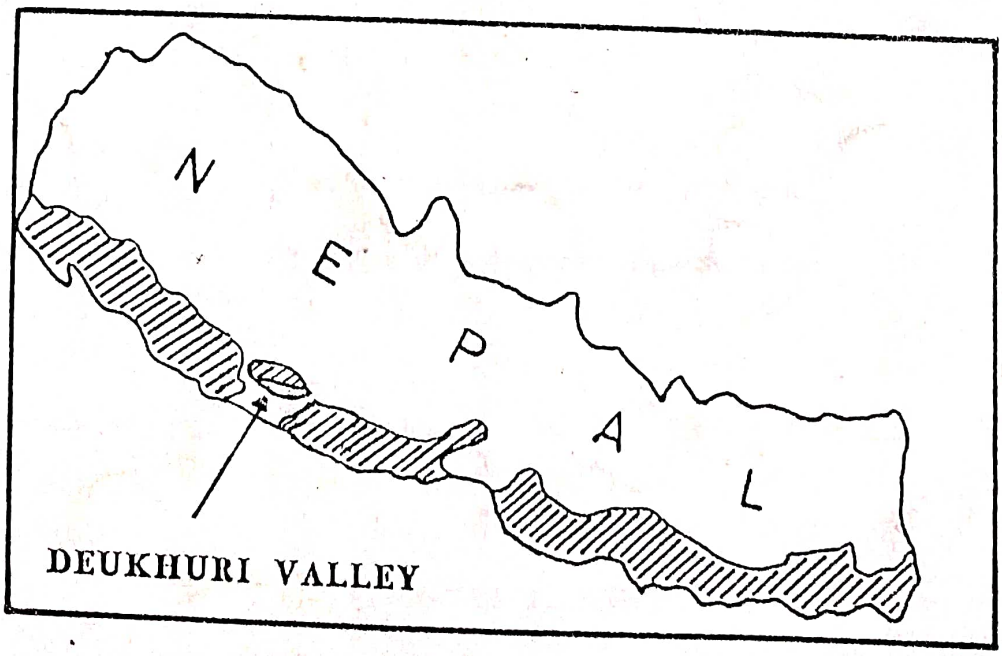
DEUKHURI VALLEY

SHALLOW WELLS DRILLING, TESTING AND MONITORING IN 1987-89

BASIC DOCUMENTATION AND PRELIMINARY INTERPRETATION



TECHNICAL REPORT NO.9



KATHMANDU, JUNE 1989

GWRDB-UNDP PROJECT NEP/86/025

SHALLOW GROUND WATER EXPLORATIONS IN TERAI

TECHNICAL REPORT NO. 9

DEUKHURI VALLEY

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BASIC DOCUMENTATION AND PRELIMINARY INTERPRETATION

Executing Agency: United Nations Department of Technical

Co-operation for Development

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KATHMANDU, JUNE 1989

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 1987-89. 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.

ABBREVIATIONS:

UN/DTCD - United Nations Department of Technical Co-operation for Development

UNDP - United Nations Development Programme

GWRDB - Ground Water Resources Development Board

GDC Groundwater Development Consultants (International) Ltd.

ADBN - Agricultural Development Bank of Nepal

ADB - Asian Development Bank

STW - Shallow Tube Well

DW - Dug Well

MCM - Million Cubic Meters

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APPENDICES

FIGURES

1. BACKGROUND INFORMATION

1.1. NEP/86/025 Project Document Details

The project NEP/86/025 - Shallow Ground Water Investigations in the Teral - 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 Irrigatlon 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) - 10 newly drilled shallow wells between January and June 1988.

(b) Tubewells drilled for Ground Water Investigations by GWRDB since 1985 to 1987 - 12 wells.

(c) Pumping tests conducted in project and ADBN wells in 1988.

(d) Water level observations since May 1987.

(e) Several field trips by NEP/86/025 project staff.

(f) Book "Geology of Nepal" by C.K.Sharma (1977).

1.3 Location, Size, Climate, River Flow

Deukhuri valley is in Dang district, which belongs to the Mid- Western Region (in addition to Banke and Bardiya districts). The location of Deukhuri valley is shown in Figure 1. This report covers only the drilling activities,lithology, and hydrogeological characteristics of the shallow aquifer in the valley covering an area of about 700 km^2.

The main characteristics of the climate in Deukhuri valley, as well as in the whole Terai, is monsoon rainfall which occurs between June and September delivering an average of 85% of the total annual rainfall. For the purpose of this report the data collected in two rainfall stations, Ghorahi and Koilabas (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 for the correlation between shallow water level fluctuation and the rainfall.

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 and 1988 will be discussed in Section 4.2. The mean annual rainfall is about 1900 mm.

The major potential surface water source for supplementing natural rainfall is the Rapti River which flows from east to west almost in the centre of the valley. This is a perennial river. The river gauging stations are at inlet (Bhalubang) and outlet (Amile) points of the valley, their long term mean discharges are 93 and 122 m^3/sec respectively. For the locations of these points, see Figure 1.

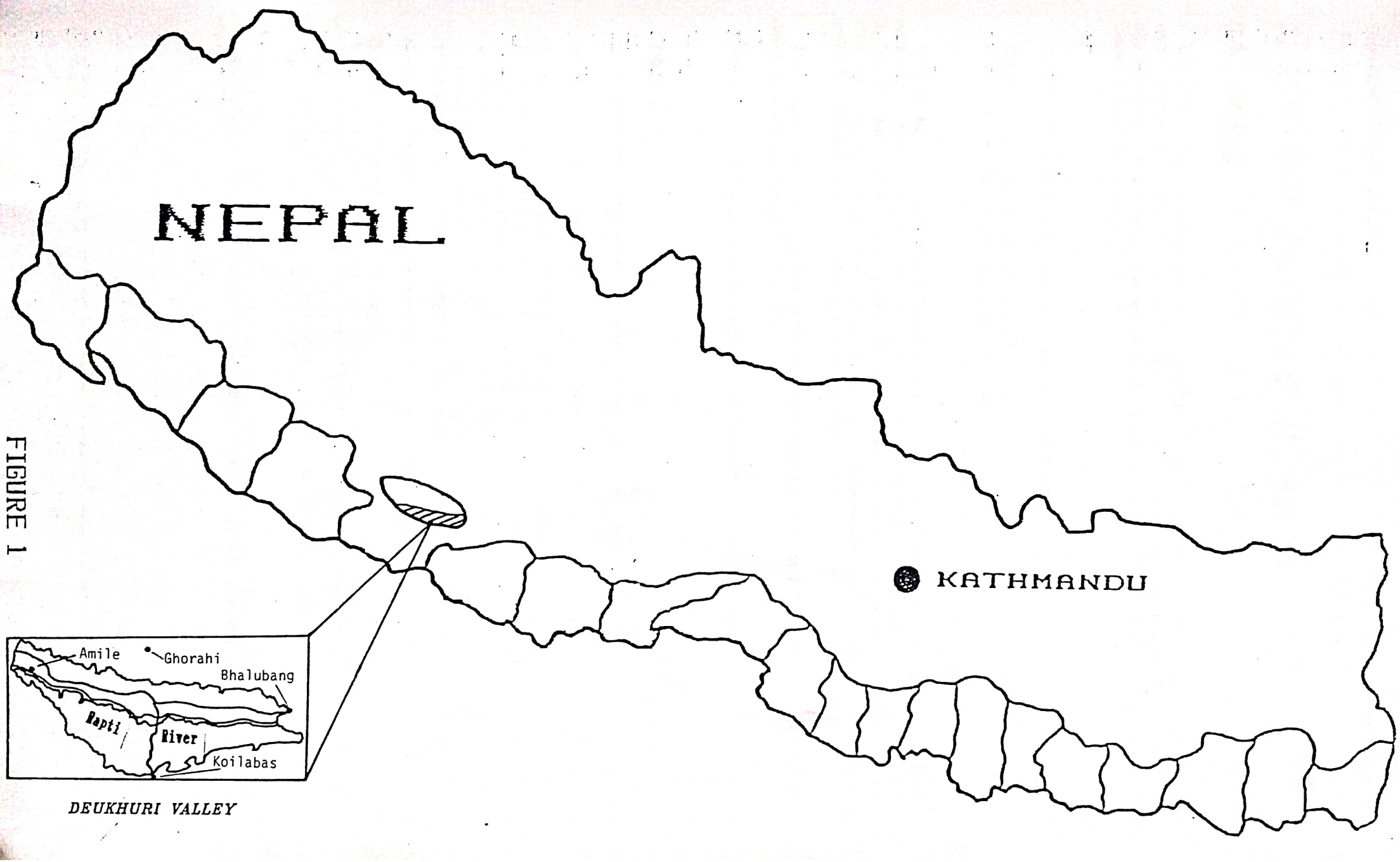

NEPAL
KATHMANDU
Amile
Ghorahi
Bhalubang
Rapti
River
Koilabas
DEUKHURI VALLEY

FIGURE 1

2. PROJECT ACTIVITIES IN 1987/88

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 Deukhuri valley was prepared about a year-and-half ago providing for drilling of 5 wells with an average drilling depth of 35 m. The total drilling metrage in Deukhuri valley was estimated at 175 m.

Here below the planned and actual implementation is shown:

Planned: 5 STW Total drilling metrage: 175 m
Actual: 6 STW Total drilling metrage: 174 m

With respect to both, number of drilled wells and their total drilled metrage, the implementation was almost same as programmed. The implementation compared to the design is illustrated in Figures 2 and 3. The map with locations of all "project" wells is shown in Appendix 1. Eighteen lithological logs with other well construction data are appended in the group of Appendices 3 (3/1 through 3/18). Lithological cross-sections are presented in Appendices 4 (4/2 through 4/4).

The actual number of drilled wells in Deukhuri valley by this project is 6. All of them were completed. Average depth of completed wells is 29 m.

The table here below presents the most pertinent data on "project" well drilling.

TABLE 1.

No.	Name	X	Y	Z	Depth	Screen Type
1	Hasnapur	645250	3082875	235.36	38.1	S & W
2	Gahira Gaon	644000	3080625	239.53	24.4	S
3	Manpur	649125	3079500	245.66	26.0	S
4	Balapur	650250	3077375	251.49	38.4	W
5	Gobardiya	660250	3077375	276.56	27.4	S & W
6	Masuriya	670375	3079625	289.71	19.8	S

S = Slotted Pipe , W = Wire Wrapped.

Notes: (1) X and Y coordinates are taken from the 1:500,000 map of Nepal, as 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.

(2) Z is the absolute elevation of the well above the mean sea level. The elevation was supplied by SWISSAIR Photo+Surveys Ltd., under a subcontract. The land-surface surveying was completed in March 1989.

NEP/86/025 NUMBER OF WELLS & PUMPING TESTS IN DEUKHURI VALLEY (1987/88)

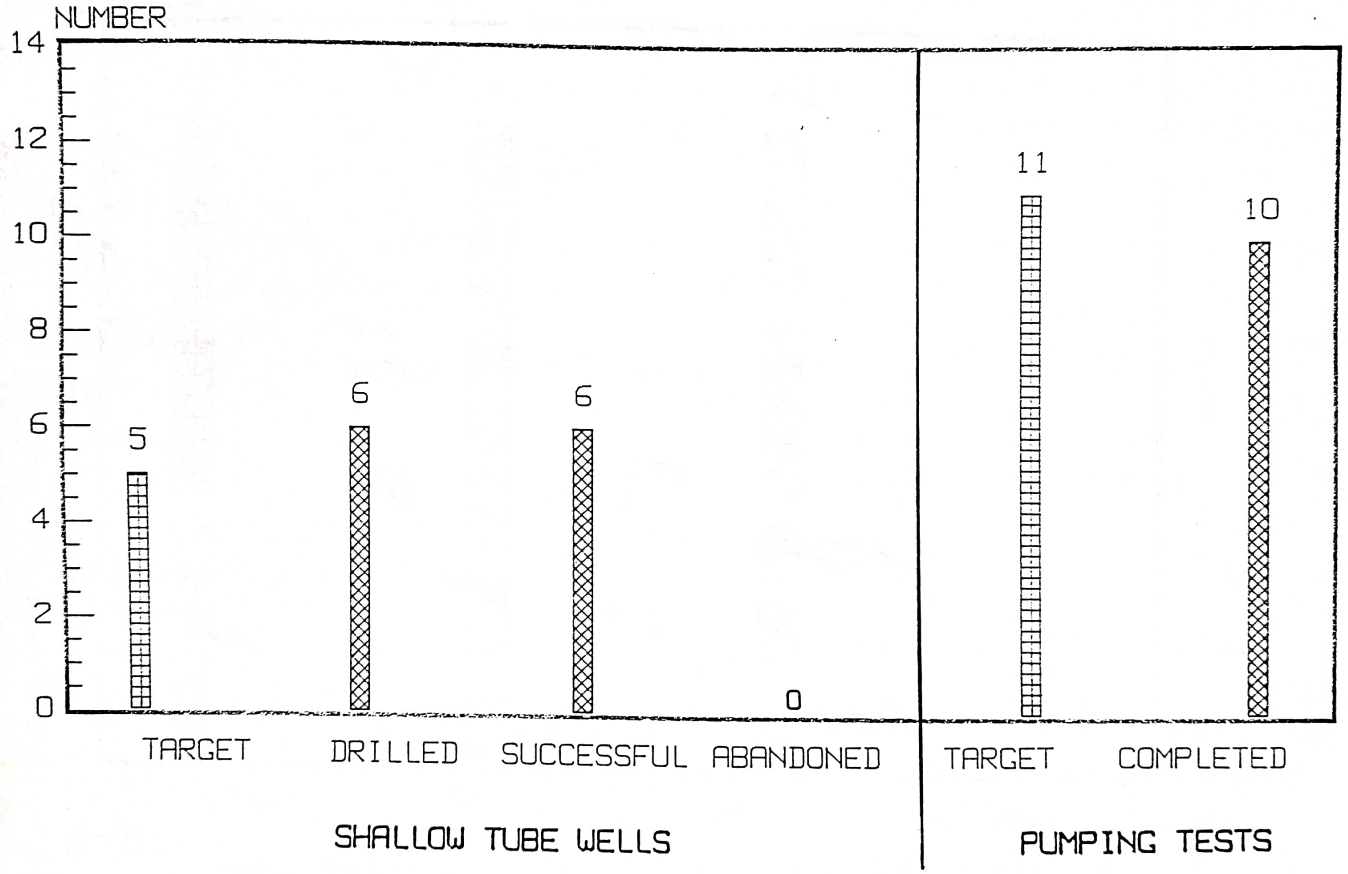


FIGURE 2

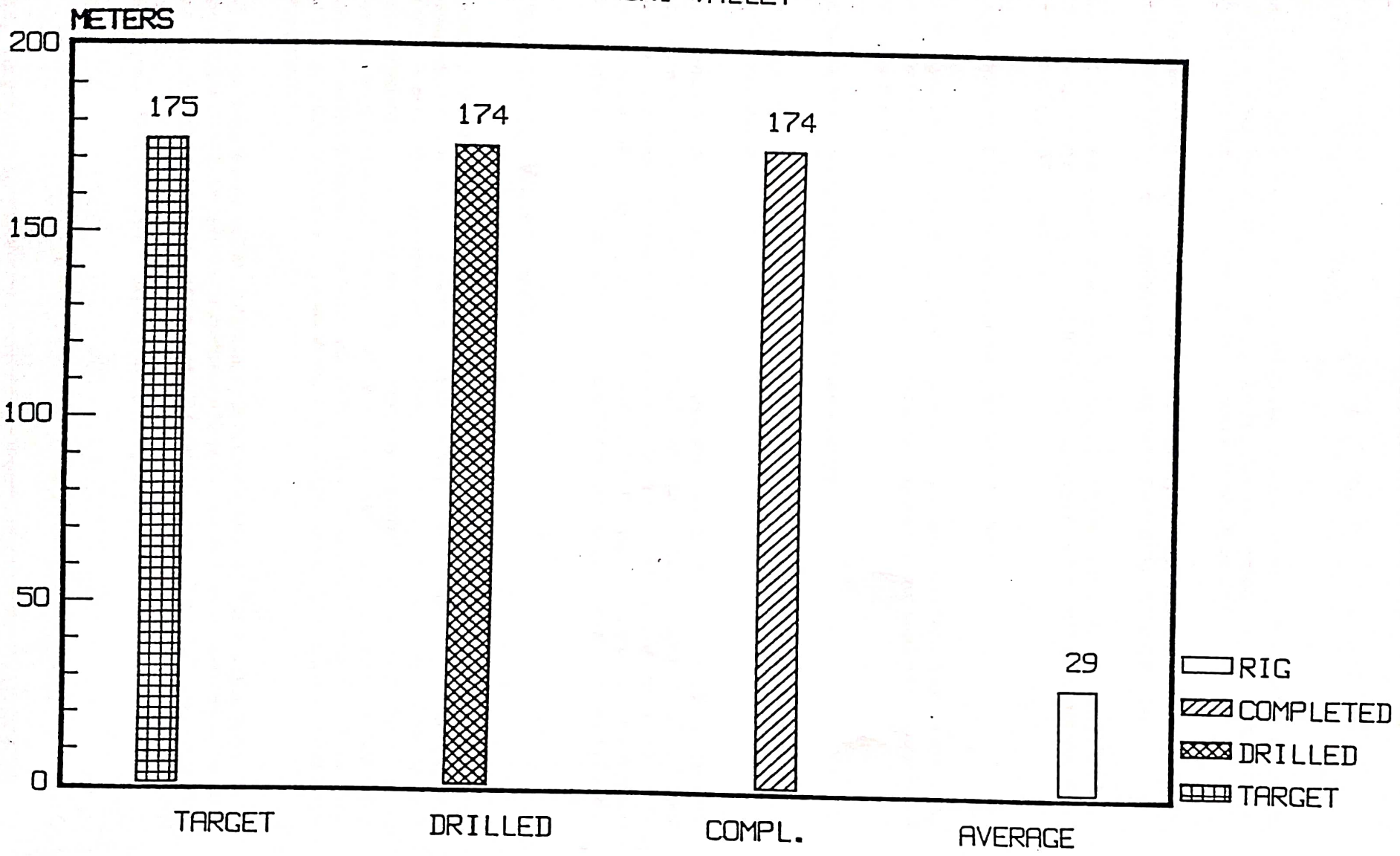

NEP/86/025 DRILLING METRAGE
IN DEUKHURI VALLEY
METERS
200
150
100
50
0
175
174
174
29
TARGET
DRILLED
COMPL.
AVERAGE
RIG
COMPLETED
DRILLED
TARGET

FIGURE 3

The deepest well is 38.4 m deep, and the shallowest 19.8 m. All of 6 wells were drilled by drilling rig. It has been reported that the formation in Deukhuri valley is not as hard as the formation in Dang valley. Several private shallow wells along the Rapti river have been constructed by manual methods.

2.2. Testing Shallow Wells

It was programmed for the pump testing of 11 shallow tube wells in total (5 newly drilled and 6 to be selected from existing shallow wells). Out of this, ten wells had been tested. Two tests were conducted with observation well nearby. For the location of all tested wells see Appendix 1.

Out of 6 newly drilled "project" wells, in one well the pumping test could not be executed because the static water level at the time of completion was too deep to run a test with a centrifugal pump.

All pumping test interpretations 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 running pumping tests the following problems have been identified:

(a) Pumping equipment not adequate for all situations. The suction range of centrifugal pump limited to about 7 m below the pump discharge point restricts the possible dynamic depth of pumping. Pump discharge fluctuates during the test.

(b) Pump discharge measuring instrument not always reliable.

(c) Measurements of water level during the pumping and/or recovery periods are sometimes questionable (late, improvised).

In most tested wells the duration of pumping was between 300 and 360 minutes. In only two tests the time of testing was 180 minutes. Considering that the dynamic levels stabilized after 3 to 5 hrs, the test duration of four hours seems to be sufficient. It would have been very useful to have had more observation wells included in the testing program. For that reason, all of the "project" wells should have been located nearby existing shallow drilled wells which could then be used as observation wells during the test.

2.3. Monitoring Water Levels

In Technical Report No. 2 three maps from Deukhuri valley were presented showing the maximum and minimum depths to water table in 1987 and the rise of water levels between the minimum and maximum of 1987. In May 1987, water levels were monitored in dug wells. Later, each newly drilled "project" well was included into the monitoring network. The idea was to gradually replace the original network of dug wells with newly drilled wells of which lithology is known, transmissivity eventually calculated and land surface elevation surveyed. This "new" monitoring network is shown in Appendix 2. In addition, several GWRDB drilled shallow wells are taken into consideration for the monitoring purpose to fill the gap in the network.

Depth to water table is observed in either monthly or bimonthly intervals. The evolution of water table in shallow aquifers of the Deukhuri valley is illustrated with several appendices in this report (Appendices 8: the rise of water table between May and October 1987; depths to water table in April and August 1988; the rise of water table between April and August 1988; and depth to water table in April 1989). Individual hydrographs for some of monitored wells are presented in Appendices 10.

3. SHALLOW AQUIFER LITHOLOGY AND AQUIFER PARAMETERS

3.1. Lithology

According to C.K.Sharma (1977), the northern and southern rims of Deukhuri valley contain Pliocene to Pleistocene deposits of conglomerate, micaceous friable sandstone, clay and lignite.

Project wells have penetrated through the upper 30 or so meters of an alluvial sequence mostly along the Rapti river. GWRDB wells have gone deeper. It is noticed that the areas along the Rapti river are composed of interlocked alluvial deposits made by the rivers flowing in the valley and by outwash from surrounding hills.

The lithology of the shallow ground water system in Deukhuri valley is known up to some extent from 6 "project" wells and from 12 wells drilled from 1985 to 1987 by GWRDB. There was no attempt to connect permeable layers in lithological cross sections. 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. Sudden changes in lithology can be noticed from the lithological logs of wells at Lamahi and Satbariya.

Out of total 497 meters (drilled metrage in 6 "project" wells of 174 m and taking 30 or so meters lithology of GWRDB wells which is 323), 264 m are sand and gravel deposits. This means that about 53% in an average shallow well is composed of sand and/or gravel. (An "average" well depth considered is 30 m deep, out of which 16 m are composed of permeable, and 14 m of impermeable deposits). The percentage of permeable materials in Deukhuri valley (53%) is almost same as in Sunsari (56%) and higher than in Kapilvastu (32%), Rautahat (39%), Nawal Parasi - West (48%) and Dang (48%).

The lithological cross sections I - I',II - II' and III - III' show the followings.

The eastern part contains coarse grained permeable materials, but the central and western parts contain rather mixed type: gravel with sand. In addition to this, the ground surface is permeable in the central and western parts. The changes occur not only in east-west direction but also in the north-south direction. The well at Balapur shows 11.6 m. of sand and gravel at the top, whereas the well at Manpur about 2 km. northwest of Balapur shows 3 m. of sandy clay at the top.

Considering the lithology of the shallow aquifer in Deukhuri valley, one may conclude that in most of the places near the Rapti River there are chances of getting at least 4 meters of sand and/or gravel deposits within a depth of 30 meters. 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 the shallow aquifers are obtained from pumping tests run on 5 "project" wells, and 5 ADBN 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 some 10 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. Transmissivities of shallow aquifers are shown in Appendix 6. 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 10 values which is not sufficient to accurately describe the whole valley.

Six more GWRDB wells are available for testing. After the completion of those tests, the transmissivity distribution will be better defined.

The interpretation shall be attempted with information in hands.

TABLE 2.

Well		Thickness (m)	Transmissivity (m^2/day)	Conductivity (m/day)	Lithology
DKSTW-1	Hasnapur	24.1	4610	191.3	G & S
DKSTW-2	Gahira Gaon	21.6	9925	459.5	G
DKSTW-3	Manpur	11.6	2000	172.4	G & S
DKSTW-4	Balapur	13.2	1585	120.1	G
DKSTW-5	Gobardiya	15.8	990	62.6	G

Note:- G = Gravel, S = Sand

It can be seen in the above table that in all 5 wells, the conductivity has matched with the corresponding lithology. Highest transmisssivity is found in the central part of the valley (Gahira Gaon - 9925 m^2/day). The pumping test result of the well at Manpur showed 477 m^2/day of transmissivity, whereas its observation well (ADBN) at a distance of 149 m. showed transmissivity of 10682 m^2/day. The driller's log of Manpur project well shows 11.6 m. of sand and gravel, of which the maximum transmissivity can be considered as 2000 m^2/day. Therefore, for the interpretation purpose this value has been taken into consideration. Among the five ADBN wells, the lowest transmissivity found is 700 m^2/day in the well at Satbariya (north western part of the valley) and the highest is 4928 m^2/day in the well at Mourighat (north eastern part of the valley).

Considering the transmissivity of the shallow aquifer in the pump tested area, it can be concluded that the area is quite suitable for shallow ground water development.

4. FLUCTUATIONS OF SHALLOW WATER TABLE

4.1. Monitoring Network

The central part of Deukhuri valley along the Rapti river is covered with observation network. In May 1987, the monitoring of shallow water table started by observing depth to water table in dug wells and still continuing. After the completion of "project" wells, they were also included in the network. Monitoring of GWRDB drilled wells was being done continuously right from their completion. Now, it is recommended to continue with routine observations on all newly drilled project wells, shallow drilled GWRDB wells and in addition on seven dug wells in order to fill the gap between the drilled wells for the purpose of this project. This actual monitoring network contains 19 wells in total and is shown in Appendix 2.

4.2. Rainfall in Deukhuri Valley in 1987/88

To understand better the rise of shallow water levels from the driest month to wettest month (either 1987 or 1988) one should look at rainfall in the June-September period. As shown in Figure 1, two rain gauging stations, one at the southern edge of Deukhuri and the other in the Dang valley floor are considered for the present purpose.

The mean monthly and annual rainfall in Deukhuri valley are shown in Figure 4. The annual sum in two stations were as follows.

TABLE 3.

Station	Annual Rainfall in mm 1987	1988
Ghorahi (Dang)	2145	1804
Koilabas (Deukhuri)	1636	2479

It can be seen from above that there was higher rainfall in 1988 than in 1987 recorded at Koilabas, whereas it was in opposite order in the case of Ghorahi. In average, the rainfall in 1988 was higher (by 256 mm) than in 1987.

The monthly rainfall is plotted alongside with water table fluctuations in Appendices 7 to indicate the relationship between the rainfall and water table rise and decline in the period from May 1987 through December 1988 at selected locations from eastern, central and western parts of the valley.

In Appendix 7/1, it can be seen that the higher rainfall in 1988 than in 1987 is reflected in Unchanibu well (the remaining two project wells do not have data from 1987). The fluctuation trend of all three wells are similar and there is a clear decrease in depth to water table from the eastern part to the western part.

In Appendix 7/2, the wells from central and western parts showed the maximum water level higher in 1988 than in 1987, whereas the well from eastern part showed opposite behaviour. The fluctuation trend of the wells from eastern and western parts are similar, but the well from central part showed very deep water table from November 1987 to January 1988, which could be due to mistake in measurements.

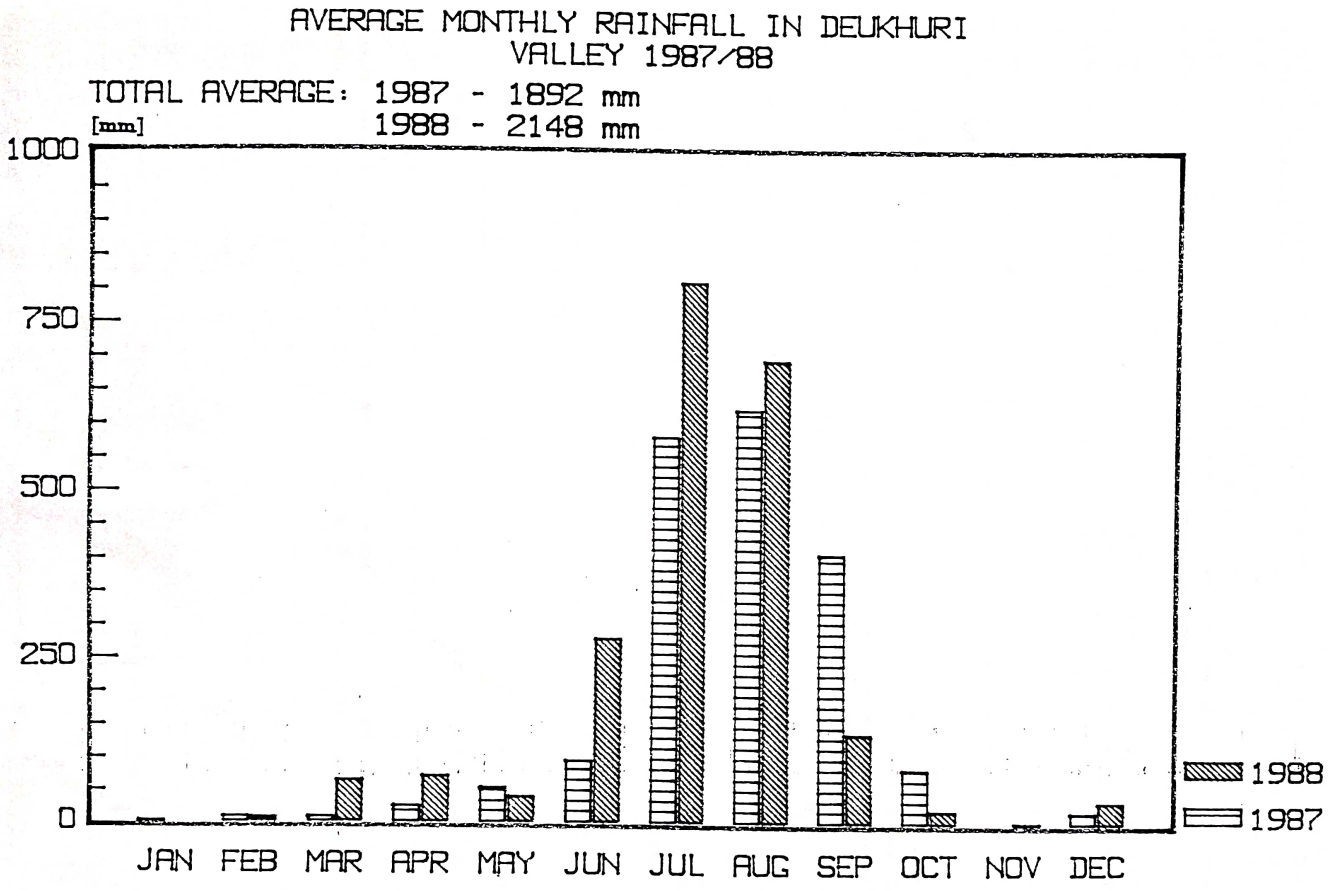

AVERAGE MONTHLY RAINFALL IN DEUKHURI VALLEY 1987/88
TOTAL AVERAGE: 1987 - 1892 mm
1988 - 2148 mm
[mm]
1000
750
500
250
0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1988
1987

FIGURE 4

4.3. Shallow Ground Water System Hydrodynamics

Hydrodynamics of the shallow ground water system in Deukhuri valley in 1987, 1988 and 1989 is presented in Appendices 8/1 through 8/5, 9/1 through 9/3, and 10/1 through 10/3. The group of Appendices 8 refers to the depth to water table in relative terms (pre-monsoon, post-monsoon, rise of levels in 1987 and 1988). Similar maps have been already presented in Technical Report No.2 for the year 1987. The Appendices 9 present contour maps of water levels in April and August 1988, and in April 1989. The Appendices 10 show hydrographs of selected wells (May 1987 - May 1989) .

The map of rise of water table from May through October in 1987 (Appendix 8/1) shows that the maximum rise was 4.0 m. at Narti, which is the northeastern part of the valley. Except in Narti, Gobardiya and Masuriya (eastern most part of the valley) areas, the rise of water level was less than 3 m.

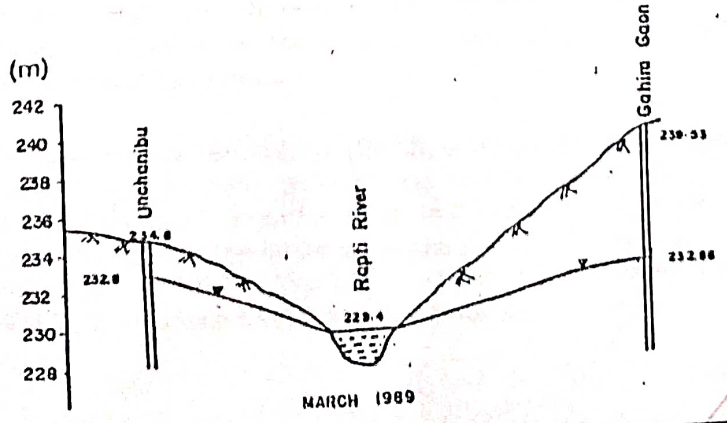
The map of maximum depth to water table (Appendix 8/2, April 1988) shows the following. The deepest water table was in Barakhuti in the eastern part of the reported area, 15.6 m. In some wells the maximum depth was in May and June. In most of the area the levels in April 1988 were about 6.0 m under land surface.

The map of minimum depth to water table (Appendix 8/3, August 1988) shows the following. In most of the area , the water table was within 4 m. It was deeper in the eastern part and Phalkapur area. In some wells , the minimum depth was in July or September or October. In the central part, the minimum depth to water table varies from 0.81 m. in Manpur to 3.85 m. in Pratappur, in the eastern part from 8.95 m. in Masuriya to 12.05 m. in Barakhuti, and in Phalkapur area, more than 8.0 m.

The rise of shallow water levels in the monsoon season (from April through August 1988) is shown in Appendix 8/4, and the behaviour of rise of levels are similar to that from May through October in the year 1987. The rise of levels started in the month of June as a direct response to June rainfall. The maximum water levels were established in August and the decline started in September. Correlating the hydrographs with rainfall, it may be concluded that the high August level is the response to rainfall of 1503 mm in July and August and the rainfall in September of 133 mm is not sufficient to keep the water at such high levels and the levels slowly but steadily declined.

The map of maximum depth to water table in 1989 (April) is presented in Appendix 8/5. This map is quite similar to the map of maximum depth to water table in 1988 (April),

Appendices 9/1, 9/2 and 9/3, present the water level contour maps in April and August 1988 and April 1989, respectively. As expected the general direction of ground water flow is from east to west. The gradient of flow in average is about 0.002, or 2 m/km. In August 1988, the contour lines are higher everywhere for about 2 to 3 m than in April 1988. The map of contours in April 1989 is about the same as the map in April 1988. The flow pattern is same in all these three maps. Although the shallow ground water flows ultimately towards west, the local flow from aquifers is to the river. This can be visualized in the sketch below. This sketch is based on the depth to water table data of March 1989 and the elevations of wells and the river surveyed by Swiss Air Photo + Surveys Ltd. in the month of March this year.



The absolute elevations in meters of some wells near the Rapti on both sides north and south and river itself at several points from east to west are presented below in Table 4., in order to show the comparison of elevations of the river and water levels in the shallow aquifers.

TABLE 4.

North	Rapti River	South
Sisaniya (264.8)	263.3	Gobardiya (269.27)
	241.2	Balapur (246.14)
	237.9	Manpur (243.83)
Hasnapur (233.56)	232.3	
Unchanibu (232.88)	229.4	Gahira Gaon (232.86)

The group of Appendices 10 shows the following.

Appendix 10/1 presents the hydrographs of all project drilled shallow tube wells. The period of hydrographs is from March 1988 to May 1989. Among the six wells, four wells showed maximum level (minimum depth to water table) varying from 3.5 m to almost 8 m. and minimum level (maximum depth to water table) varying from 6.0 to 10.5 m. below ground surface and two wells showed maximum level near the ground surface and minimum level at about 2 m. In all six wells the difference between the maximum depths to water table in 1988 and 1989 is negligible.

Appendix 10/2 shows the hydrographs of 6 selected shallow wells constructed by GWRDB. The period of hydrographs is from July 1987 to May 1989. It is obvious that the maximum level is higher in 1988 as compared to that of 1987. Out of six, three wells show that the 1987 maximum and minimum levels were found to be in July and December respectively, which seems to be a mistake in measurements. Regarding the minimum levels, 1987 does not have pre-monsoon data. While comparing 1988 and 1989 data, one can see that in three wells, the minimum levels are higher in 1988 than in 1989 and the remaining three wells show opposite behaviour.

The final Appendix 10/3 presents May 1987 - May 1989 hydrographs of 6 selected dug wells. It is obvious that the maximum level is higher in 1988 as compared to that of 1987. Out of six, one well shows that the 1987 maximum and minimum levels were found to be in July and December, which seems to be some mistake in measurement. Comparing the minimum levels in 1987, 1988 and 1989, it is obvious that the levels are decreasing from 1987 to 1989 in five wells and the 1988 minimum level is lower than that of 1989 in Kalakatti well, which is in the easternmost part of the valley.

5. ASSESSMENT OF WATER RECHARGE AND DISCHARGE

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 and is being discharged into the Rapti river flowing in the center from east to west. Areas with permeable ground surface are located in the central part of the valley.

(2) The amount of water infiltrated into the shallow aquifers is discharged westwards eventually to the Rapti river and leaves the valley in the form of surface runoff. The annual precipitation in the valley is about 1900 mm. Even if, only 10% of this amount is infiltrated into the aquifers over an area of 700 km^2, the total volume would be 133 MCM.

(3) A tentative estimate on the possible recharge is made by taking the effective porosity of sand and gravel aquifers as 15% and the average rise of water table during monsoon as 2.3 m. over an area of 525 km^2 (from Satbariya area to the eastern end of the valley). This amounts to be about 181 MCM per year. Since the annual average rainfall in 1988 is nearly equal to the long term annual average, this estimate can be considered as average annual recharge.

(4) The amount of outflow through 11 km. wide section taken near Satbariya is calculated approximately with gradients from the group of appendices 9 and transmissivities from Appendix 6. The transmissivity is about 2500 m^2/day in average. The gradient is about 0.0017. The volume of water that may be outflowing is about 468,000 m^3/day or about 171 MCM in one year, which is a large portion of the potential annual recharge in the valley.

(5) The remaining 10 MCM of infiltrated water can be balanced by possible evapotranspiration process occuring in the areas where water table is close to or within 3 m. from ground surface for a considerable period. The areas where the water table is always within 3 m. are Satbariya, Unchanibu, Manpur, Balapur, Gadhawa, Gangaparaspur, Saljhundi Dhaireni and Sisaniya. Likewise, the areas where the water table is within 3 m. only for 5 to 7 months are Lamahi, Kolahi, Gobardiya, Kothari, and Phalkapur.

6. CONCLUSIONS AND RECOMMENDATIONS

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

The drilling program which was formulated about a year and half ago, was completed according to the expectations in the sense of numbers as well as total drilled metrage. Six wells were completed with the total drilling metrage of 174 m. The average depth of newly completed wells is 29.0 m, which is less than anticipated. Considering the lithology of shallow ground water system, this depth is probably adequate for the project purpose. All of 6 wells were constructed by drilling rig. It has been reported that several private shallow wells constructed by manual methods are existing in the valley along the Rapti river. The project did not experience about the manual methods, so it will be difficult to say something on advantages and disadvantages of a particular method of shallow wells construction in Deukhuri valley. Theoretically, 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 and the area with harder formation are taken into account.

In running pumping tests the following problems have been identified:

(a) Pumping equipment not adequate for all situations. The suction range of centrifugal pump limited to about 7 m below the pump discharge point restricts the possible dynamic depth of pumping. Pump discharge is fluctuating during the test.

(b) Pump discharge measuring instrumentation is not always reliable. The best method of testing would be with a 3-in flowmeter with direct reading of the flowrate in liters per second.

(c) Measurements of water level during the pumping and/or recovery periods are sometimes questionable (late, improvised).

The pump testing program in Deukhuri valley should be continued in order to fill the big gap between the wells which have been tested. If remaining wells are tested, the wealth of information and knowledge about the valley would be improved to some extent.

The wells to be tested are as follows: GW1 Unchanibu, GW3 Narti (N), GW4 Satbariya, GW5 Sundabari, GW7 Sisaniya and GW10 Narti (S).

The central part of Deukhuri valley maximum within 4 km. in the north and south along the Rapti river is covered with observation network. In May 1987, the monitoring of shallow water table started by observing depth to water table in dug wells and still continuing. After the completion of "project" wells, they were also included in the network. Monitoring of GWRDB drilled wells was being done continuously right from their completion. Now, it is recommended to continue with routine observations on all newly drilled project wells, shallow drilled GWRDB wells and in addition on seven dug wells in order to fill the gap between the drilled wells. In total, there are 19 wells considered for the continuous shallow ground water monitoring purpose.

Based on the information in hands, the hydrogeology of Deukhuri valley can be described as follows.

(a) The percentage of permeable materials (sand, gravel) in the upper 30 or so meters is about 53%.

(b) The transmissivity values obtained from 10 pumping tests carried out during present investigation shows that the areas where pumping test has been done are quite favourable for shallow ground water development. The transmissivity values vary from 700 m^2/day to 9925 m^2/day.

(c) In most of the area the depths to water table in April 1989 are within 6.0 m below the land surface. Between April and August 1988 the levels rose between 1.5 and 2.5 m in most of the area. In 1988, the rise of levels started in the month of June as a direct response to June rainfall. The maximum water levels were established in August and the decline started in September. The high August levels are the response to rainfall in excess of 1503 mm in the months of July and August. The rainfall in September of 133 mm is not sufficient to keep the water at such high levels and the levels slowly but steadily declined.

(d) The recharge comes from local infiltration of rainfall everywhere where more or less permeable surface permits and is being discharged into the Rapti river flowing in the center from east to west. Areas with permeable ground surface are located in the central part of the valley.

(e) As expected the general direction of ground water flow is from east to west. The gradient of flow is about 0.002, or 2 m/km in average.

(f) The amount of water infiltrated into the underlying aquifers are discharged westwards eventually to the Rapti river and leaves the valley in the form of surface runoff. The annual precipitation in the valley is about 1900 mm. Even if, only 10% of this amount is infiltrated into the aquifers over an area of 700 km^2, the total volume would be 133 MCM.

(g) The amount of outflow through 11 km. wide section taken near Satbariya is calculated approximately with the transmissivity of 2500 m^2/day and the gradient of 0.0017. The volume of water that may be outflowing is about 468,000 m^3/day or about 171 MCM in one year, which is a large portion of the potential annual recharge calculated as in the next paragraph.

(h) A tentative estimate on the possible recharge is made by taking the effective porosity of sand and gravel aquifers as 15% and the average rise of water table during monsoon as 2.3 m over an area of 525 km^2 (from Satbariya area to the easternmost end of the valley). This amounts to be about 181 MCM per year. Since the annual average rainfall in 1988 is nearly equal to the long term annual average, this estimate can be considered as average annual recharge.

(i) The remaining 10 MCM of infiltrated water can be balanced by possible evapotranspiration process occuring in the areas where water table is close to or within 3 m. from ground surface.

The above mentioned outcome is based on only the data available from the areas along the Rapti river. And this hydrogeological information is rather mixed type: some information is from shallow tube wells and some are from dugwells, some have only pumping test data and some with only water level fluctuation data. The wells with full hydrogeological description are scattered.

At present, very little can be said regarding the feasibility of shallow ground water development in Deukhuri valley, which is as follows.

Shallow ground water development can be done in several places along the Rapti river where the water table is within the suction lift capacity of centrifugal pump. It has been elaborated already in the text that even in the dry season the shallow aquifers of Deukhuri valley are contributing water to the Rapti river. On one hand this water can be utilized by pumping and on the other by lowering the water level in the wells, a reverse gradient from the river to the aquifers can be created which would help to keep the water table suitable for pumping for long duration. These areas are found in the form of patches, a considerable area for shallow ground water development can only be demarkated after detailed information.

Therefore, these crude conclusions can be better defined later, if further investigations covering whole valley is done. Since at present, we do not have hydrogeological information from every parts of the valley and it is reported that the geological materials are differing from the foothills to the central part along the Rapti river. So, it would be beneficial to extend the investigation towards the rims of the valley also.

The followings are recommended for the future investigations:

(i) Complete pumping tests in existing wells (UN, GWRDB and ADBN) in order to cover the area as much as possible. Use appropriate pumping equipments.

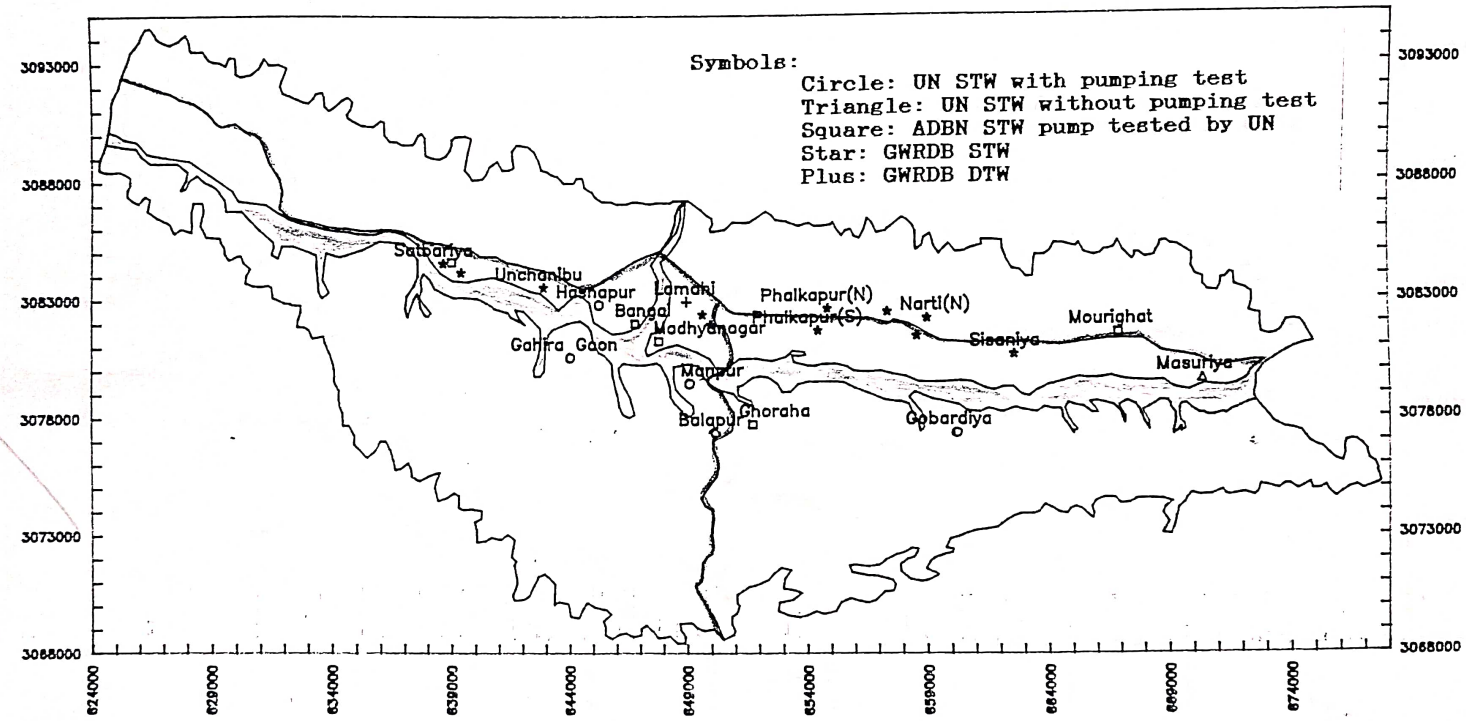
ii) Drill additional test holes in the areas where the shallow tube wells are not existing.

iii) Construct several 6" size wells nearby existing 4" size wells in the areas where water table is always below 7 m. and use the existing 4" size wells as observation wells.

(iv) Continue monitoring of all wells of the network without any interruption.

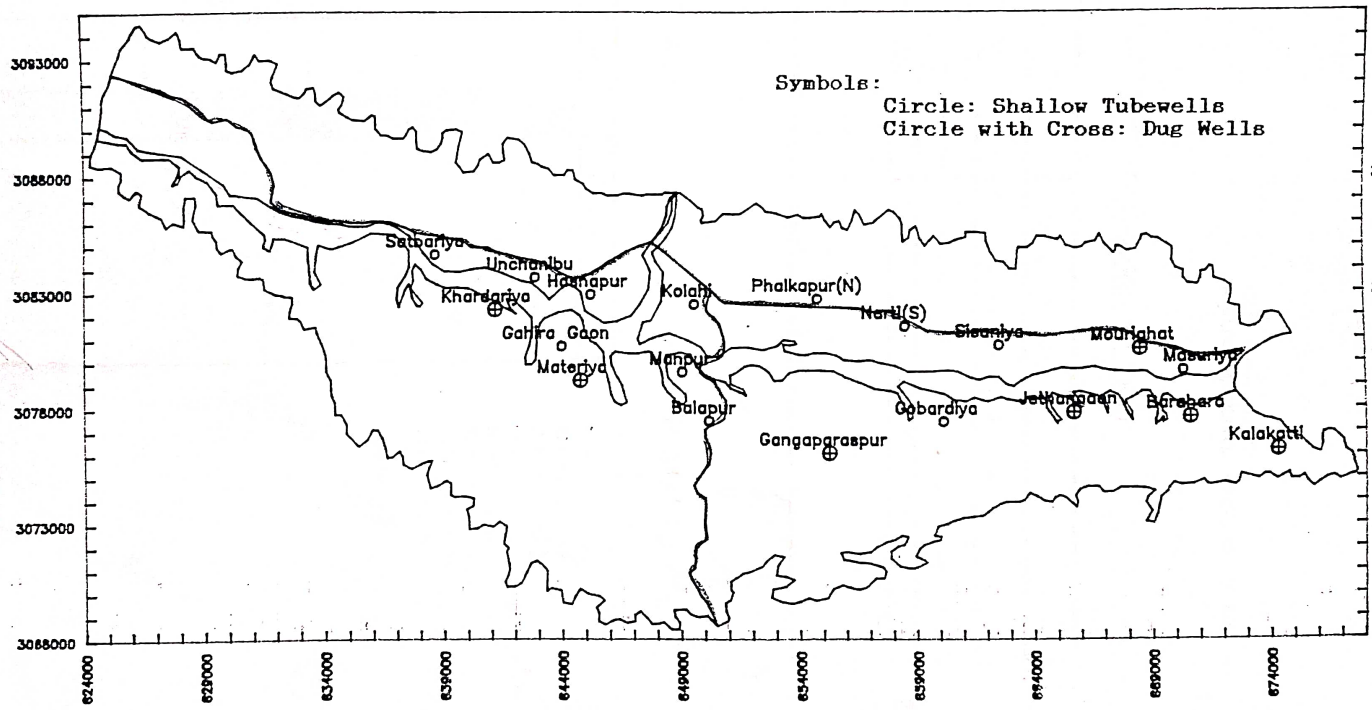
APPENDICES

DEUKHURI VALLEY – TUBEWELL LOCATION MAP



APPENDIX 1

DEUKHURI VALLEY – ACTUAL MONITORING NETWORK

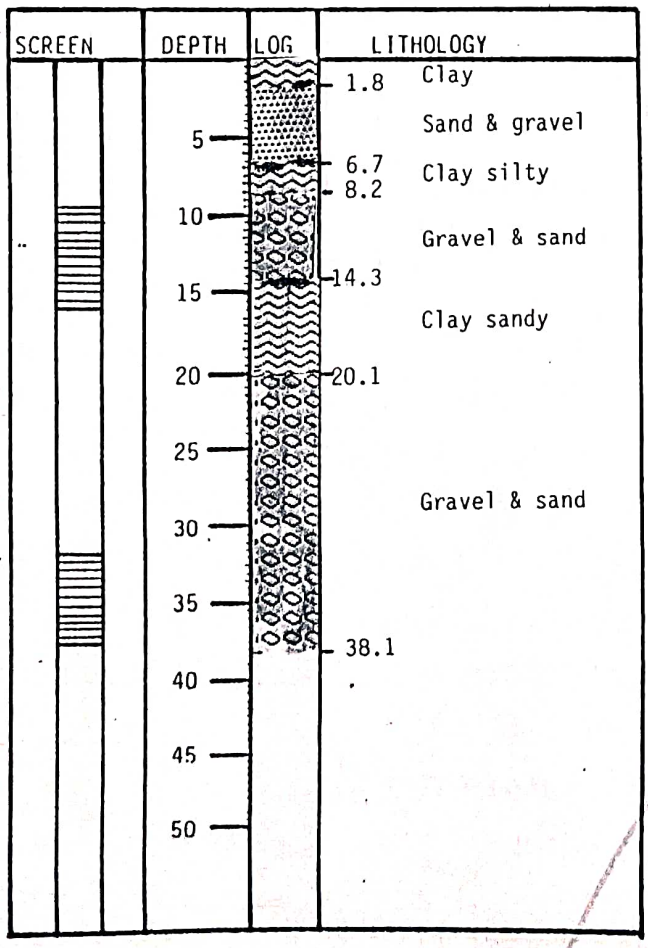


APPENDIX 2

DANG DISTRICT (DEUKHURI VALLEY)

WELL NO. DKSTW 1	LOCATION Hasnapur
ELEVATION 235.36 m	X = 645250 Y = 3082875
METHOD OF DRILLING	Rig
DRILLING DATES	2/03/88 - 4/03/88
TOTAL DEPTH	38.1 m.
COMMENTS	M.P: 0.48 m. Screen Position: 9.5 m - 15.9 m. 32 m - 37.7 m. Screen Type: Slotted & Wire Wrapped

WELL LOG



PUMPING TEST

DATE:
Q(l/s): 23
DURATION: 300 min.
TRANSMISSIVITY: 4610 m^2/day
METHOD: Jacob
STORAGE COEFFICIENT:
STATIC WATER LEVEL: 1.95 m
DYNAMIC WATER LEVEL: 6.81 m (B.G.L)

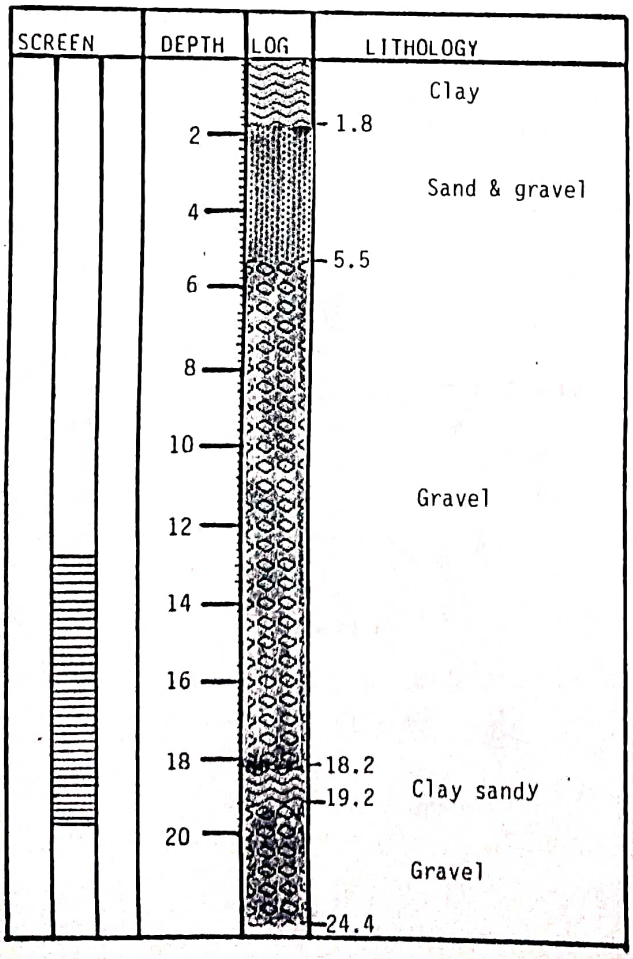
COMMENTS:

APPENDIX 3/1

DANG DISTRICT (DEUKHURI VALLEY)

WELL NO. DKSTW 2	LOCATION Gahira Gaon
ELEVATION 239.53 m	X = 644000 Y = 3080625
METHOD OF DRILLING	Rig
DRILLING DATES	05/03/88 - 07/03/88
TOTAL DEPTH	24.4 m.
COMMENTS	Screen Type: Slotted Pipe Screen Position: 12.8 m - 19.8 m. M.P: 0.30 m.

WELL LOG



PUMPING TEST

DATE:
Q(l/s): 22
DURATION: 300 min.
TRANSMISSIVITY: 9925 m^2/day
METHOD: Jacob
STORAGE COEFFICIENT: 0.00020
STATIC WATER LEVEL: 6.27 m
DYNAMIC WATER LEVEL: 7.54 m (B.G.L)

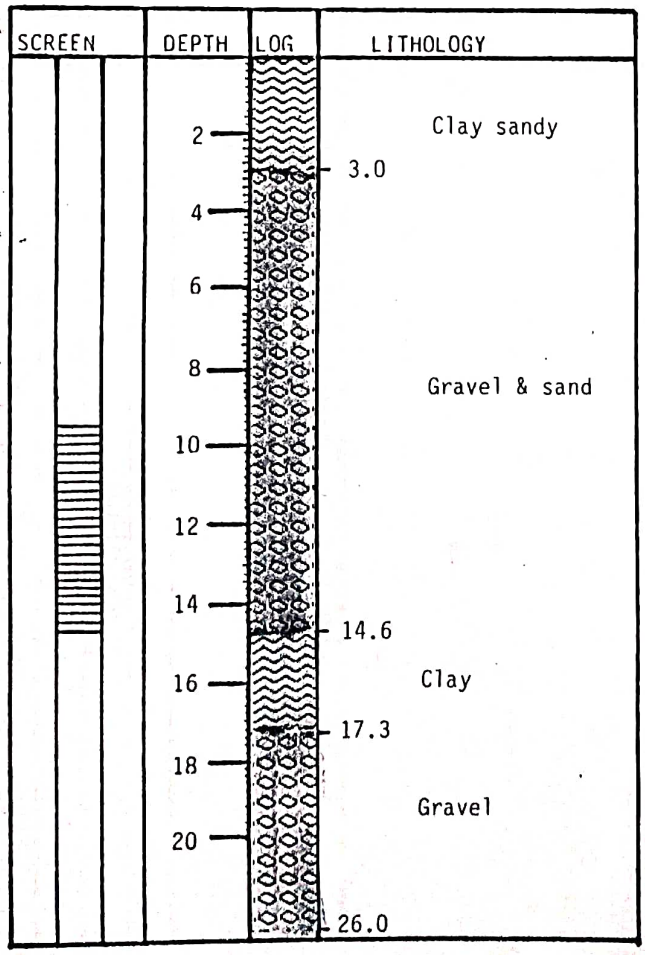
COMMENTS:

APPENDIX 3/2

DANG DISTRICT (DEUKHURI VALLEY)

WELL NO. DKSTW 3	LOCATION Manpur
ELEVATION 245.66 m	X = 649125 Y = 3079500
METHOD OF DRILLING	Rig
DRILLING DATES	7.03.88 - 9.03.88
TOTAL DEPTH	26 m.
COMMENTS	Screen Position: 9.5 m - 14.6 m. Screen Type : Slotted Pipe M.P: 0.23 m.

WELL LOG



PUMPING TEST

DATE:
Q(l/s): 22
DURATION: 400 min.
TRANSMISSIVITY: m^2/day
METHOD: Jacob
STORAGE COEFFICIENT: 0.000015
STATIC WATER LEVEL: 2.16 m
DYNAMIC WATER LEVEL: 7.63 m (B.G.L)

COMMENTS:

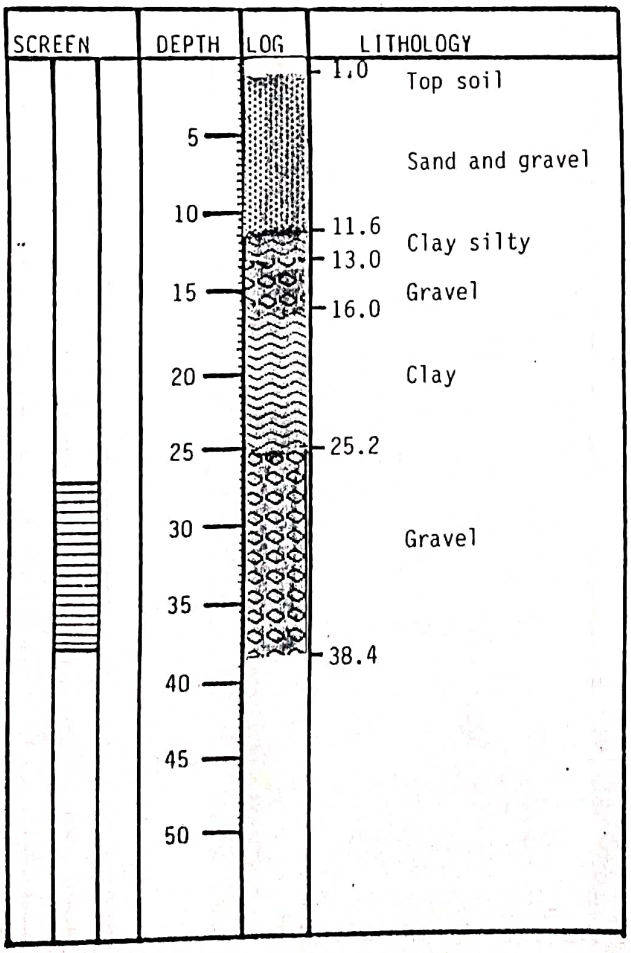
Transmissivity differs between 477 m^2/d (Pumped well) and 10682 m^2/d (Observation well).

APPENDIX 3/3

DANG DISTRICT (DEUKHURI VALLEY)

WELL NO. DKSTW 4	LOCATION Balapur
ELEVATION 251.49 m	X = 650250 Y = 3077375
METHOD OF DRILLING	Rig
DRILLING DATES	12.03.88 - 15.03.88
TOTAL DEPTH	38.4 m.
COMMENTS	Screen Position: 27.1 - 38.1 m. Screen Type : Wire Wrapped M.P: 0.38 m.

WELL LOG



PUMPING TEST

DATE:
Q(l/s): 7.0
DURATION: 3 hrs.
TRANSMISSIVITY: 1585 m^2/day
METHOD: Jacob
STORAGE COEFFICIENT:
STATIC WATER LEVEL: 4.73 m (B.G.L)
DYNAMIC WATER LEVEL: 8.72 m

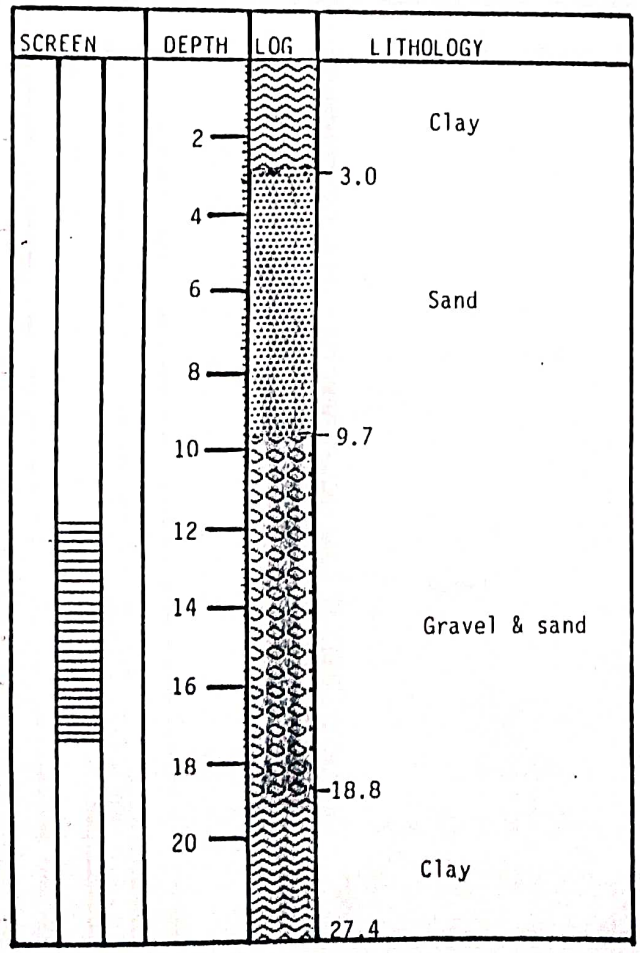
COMMENTS:

APPENDIX 3/4

DANG DISTRICT (DEUKHURI VALLEY)

WELL NO. DKSTW 5	LOCATION Gobardiya
ELEVATION 276.56 m	X = 660250 Y = 3077375
METHOD OF DRILLING	Rig
DRILLING DATES	16.3.88 - 18.3.88
TOTAL DEPTH	27.4 m.
M.P: 0.56 m.	
COMMENTS	Screen Position: 11.8 - 17.4 m Screen Type: Slotted & Wire Wrapped

WELL LOG



PUMPING TEST

DATE:
Q(l/s): 11.0
DURATION: 3 hrs. 15 min.
TRANSMISSIVITY: 990 m^2/day
METHOD: Jacob
STORAGE COEFFICIENT:
STATIC WATER LEVEL: 6.02 m
DYNAMIC WATER LEVEL: 7.4 m (B.G.L)

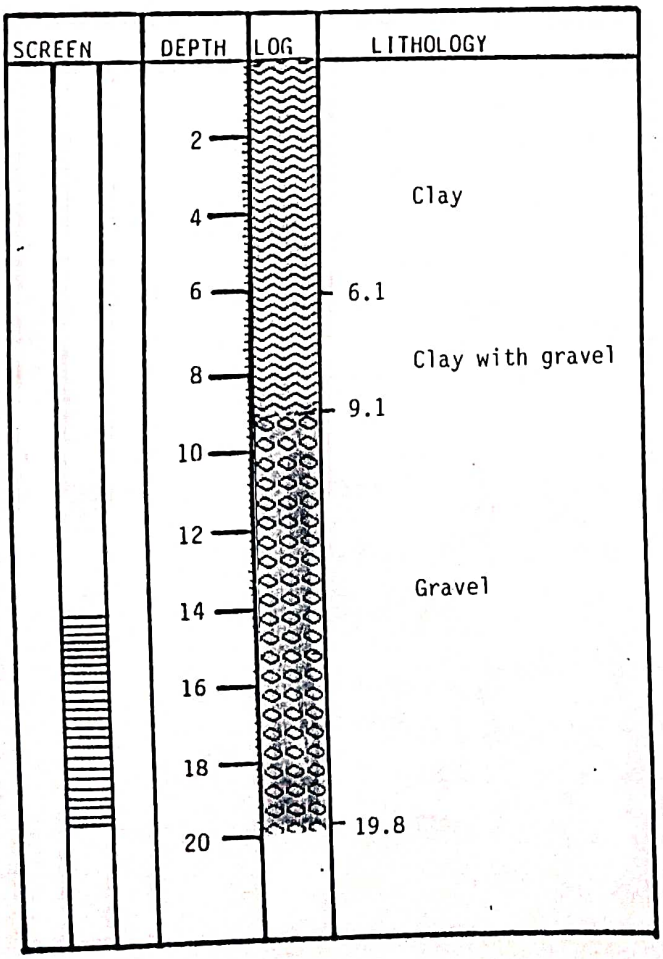
COMMENTS:

APPENDIX 3/5

DANG DISTRICT (DEUKHURI VALLEY)

WELL NO. DKSTW 6	LOCATION Masuriya
ELEVATION 289.71 m	X = 670375 Y = 3079625
METHOD OF DRILLING	Rig
DRILLING DATES	19.3.88 - 23.03.88
TOTAL DEPTH	19.8 m.
COMMENTS	Screen Position: 14.0 m - 19.5 m Screen Type : Slotted Pipe M.P: 0.39 m.

WELL LOG



PUMPING TEST

DATE:
Q(l/s): 7
DURATION:
TRANSMISSIVITY: m^2/day
METHOD:
STORAGE COEFFICIENT:
STATIC WATER LEVEL: 10.90 m.
DYNAMIC WATER LEVEL:

COMMENTS:

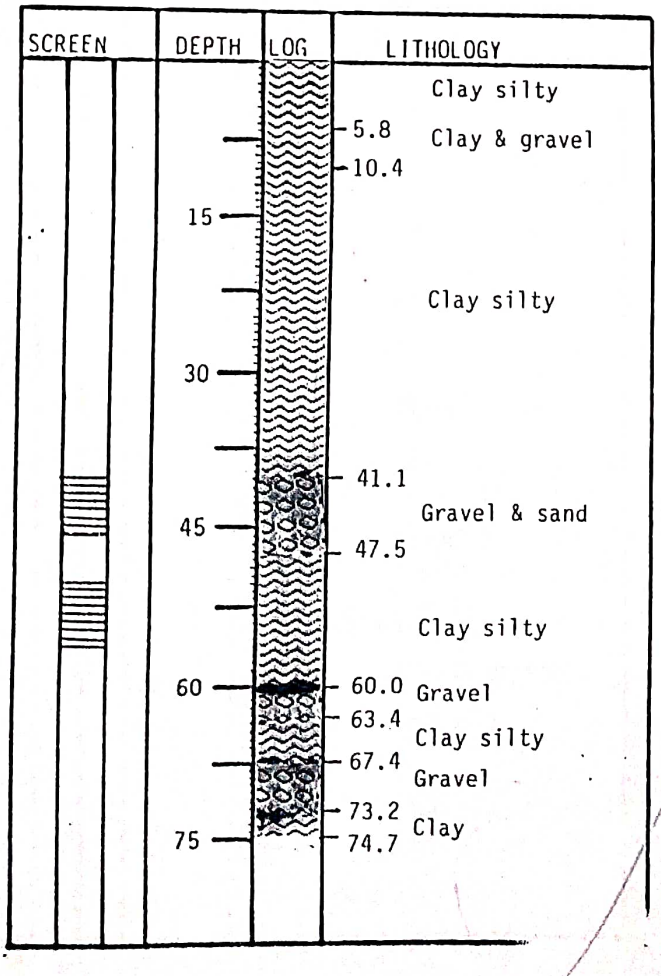
Due to deep water table, no pumping test.

APPENDIX 3/6

DANG DISTRICT (DEUKHURI VALLEY)

WELL NO. GW1	LOCATION Unchanibu
ELEVATION 234.80 m	X = 642875 Y = 3083623
METHOD OF DRILLING	Rig
DRILLING DATES	07/03/85 - 12/03/85
TOTAL DEPTH	74.7 m.
COMMENTS	M.P: 0.16 m. Screen Position: 41 - 45.9 m., 49.7 - 55.2 m. Screen Type : Slotted Pipe Well Size : 6"

WELL LOG



PUMPING TEST

DATE:
Q(l/s):
DURATION:
TRANSMISSIVITY: m^2/day
METHOD:
STORAGE COEFFICIENT:
STATIC WATER LEVEL: 2.50 m.
DYNAMIC WATER LEVEL:

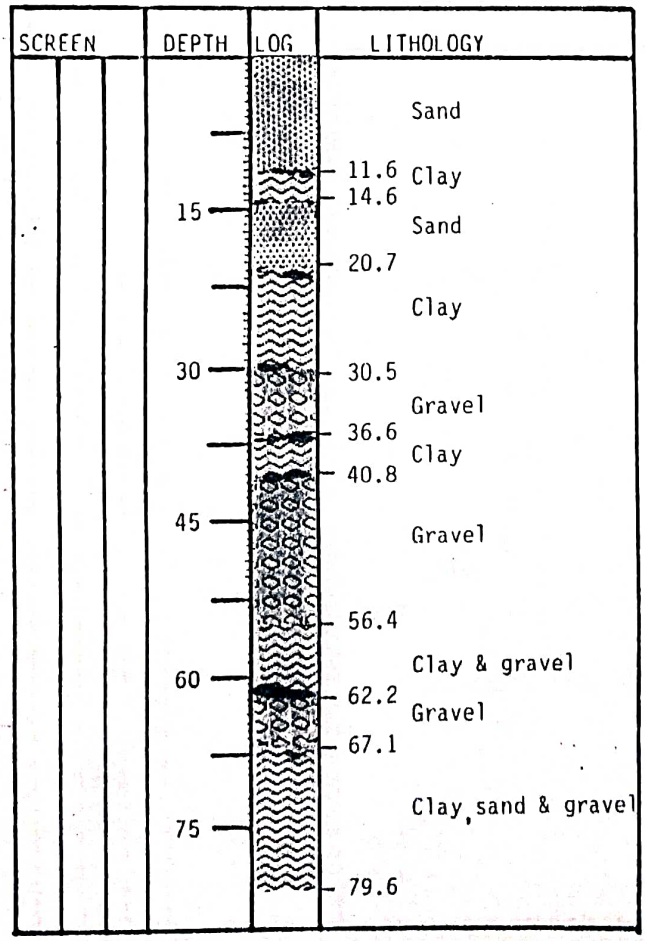
COMMENTS:

APPENDIX 3/7

DANG DISTRICT (DEUKHURI VALLEY)

WELL NO. GW2 a	LOCATION Lamahi
ELEVATION 251.30 m	X = 649000 Y = 3083000
METHOD OF DRILLING	Rig
DRILLING DATES	28/04/86 - 10/05/86
TOTAL DEPTH	111.3 m.
COMMENTS	Screen POsition: 79.6 - 84.3 m., 92.7 - 103.9 m. Screen Type : Slotted & Wire Wrapped Well Size : 10"/6" M.P: 1.18 m.

WELL LOG



PUMPING TEST

DATE:
Q(l/s):
DURATION:
TRANSMISSIVITY: m^2/day
METHOD:
STORAGE COEFFICIENT:
STATIC WATER LEVEL: 15.00 m.
DYNAMIC WATER LEVEL:

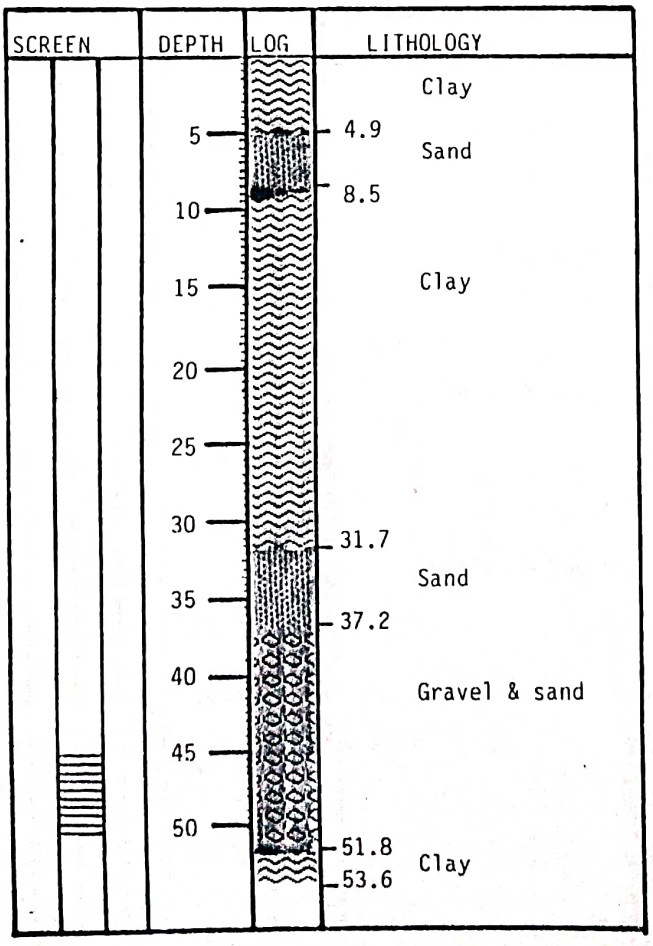
COMMENTS:

APPENDIX 3/8

DANG DISTRICT (DEUKHURI VALLEY)

WELL NO. GW2 b	LOCATION Lamahi
ELEVATION m	X = 650000 Y = 3082000
METHOD OF DRILLING	Rig
DRILLING DATES	01/05/87 - 05/05/87
TOTAL DEPTH	53.6 m.
COMMENTS	Screen Position: 45.1 - 50.6 m. Screen Type: Slotted Pipe Well Size: 4"

WELL LOG



PUMPING TEST

DATE:
Q(l/s):
DURATION:
TRANSMISSIVITY: m^2/day
METHOD:
STORAGE COEFFICIENT:
STATIC WATER LEVEL:
DYNAMIC WATER LEVEL:

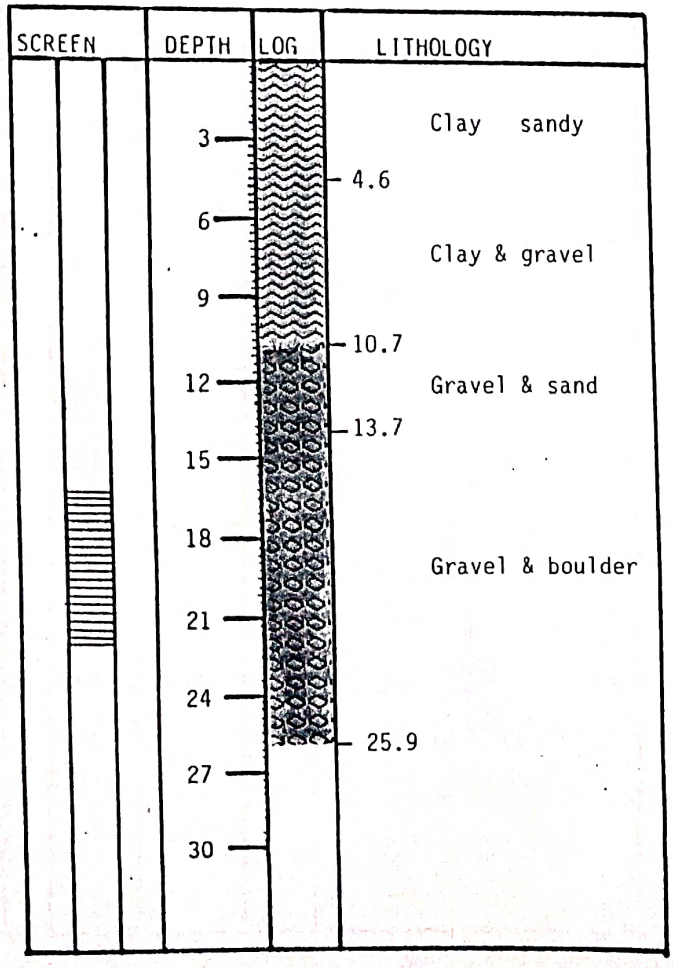
COMMENTS:

APPENDIX 3/9

DANG DISTRICT (DEUKHURI VALLEY)

WELL NO. GW3	LOCATION Narti (N)
ELEVATION 260.93 m	X = 659038 Y = 3082254
METHOD OF DRILLING	Rig
DRILLING DATES	12/01/87 - 20/01/87
TOTAL DEPTH	25.9 m.
COMMENTS	Screen position: 16.2 - 21.7 m. Screen Type :Slotted Pipe Well Size : 4" M.P: 0.81 m.

WELL LOG



PUMPING TEST

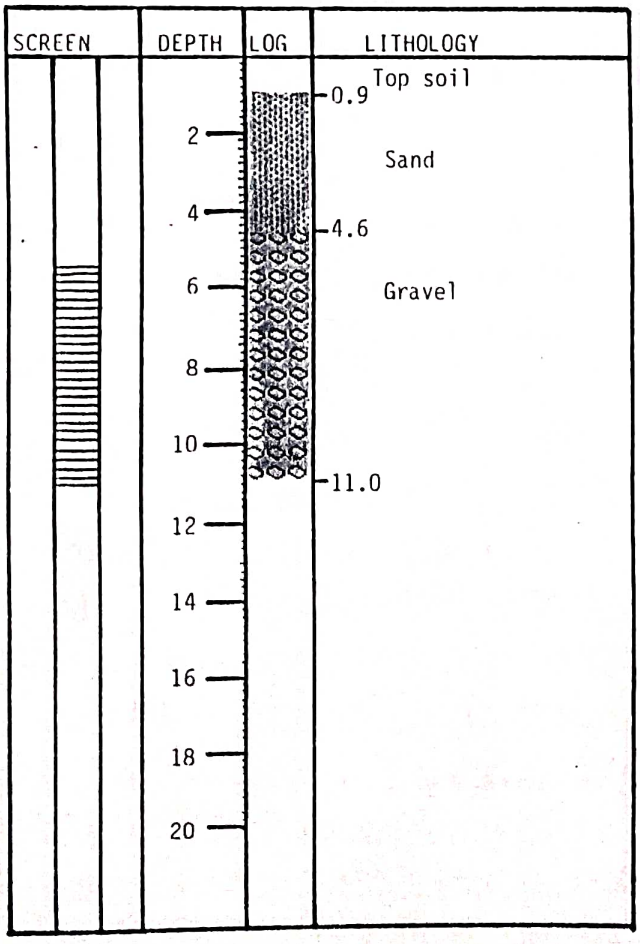
DATE:
Q(l/s):
DURATION:
TRANSMISSIVITY: m^2/day
METHOD:
STORAGE COEFFICIENT:
STATIC WATER LEVEL: 4.13 m.
DYNAMIC WATER LEVEL:

COMMENTS:

DANG DISTRICT (DEUKHURI VALLEY)

WELL NO. GW4a	LOCATION Satbariya
ELEVATION 228.29 m	X = 639375 Y = 3084250
METHOD OF DRILLING	Rig
DRILLING DATES	02/04/87 - 04/04/87
TOTAL DEPTH	11 m.
COMMENTS	M.P: 0.31 m. Screen Position: 5.5 - 11 m. Screen Type: Slotted Pipe Well Size: 4"

WELL LOG



PUMPING TEST

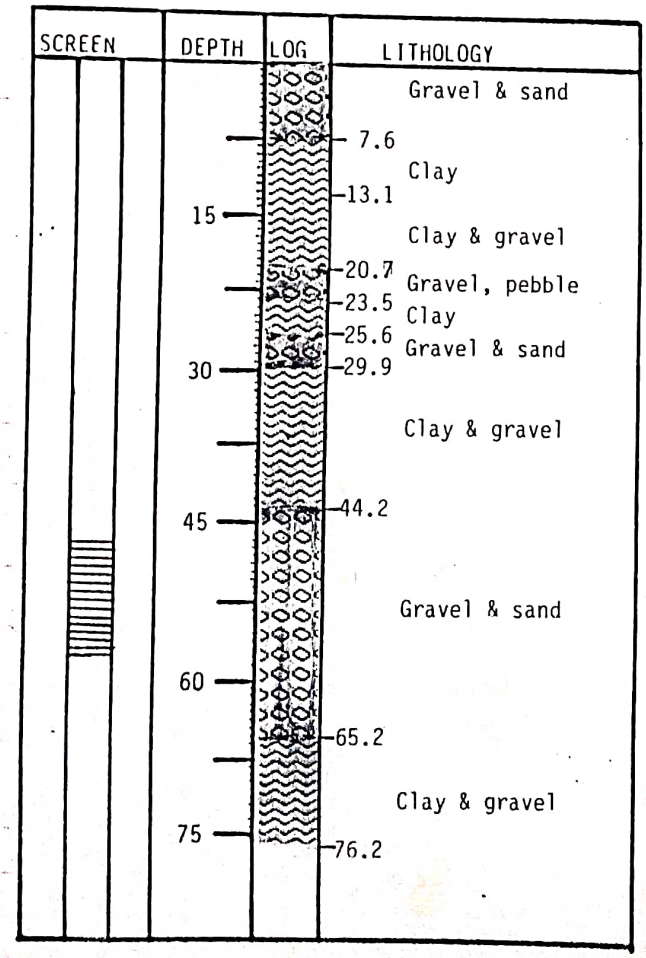
DATE:
Q(l/s):
DURATION:
TRANSMISSIVITY: m^2/day
METHOD:
STORAGE COEFFICIENT:
STATIC WATER LEVEL:
DYNAMIC WATER LEVEL:

COMMENTS:

DANG DISTRICT (DEUKHURI VALLEY)

WELL NO. GW4 b	LOCATION Satbariya
ELEVATION 227.69 m	X = 638625 Y = 3084625
METHOD OF DRILLING	Rig
DRILLING DATES	08/04/87 - 17/04/87
TOTAL DEPTH	94.5 m.
COMMENTS	M.P: 0.09 m. Screen Position: 46.6 - 57.7 m. Screen Type : Slotted Pipe Well Size : 6"

WELL LOG



PUMPING TEST

DATE:
Q(l/s):
DURATION:
TRANSMISSIVITY: m^2/day
METHOD:
STORAGE COEFFICIENT:
STATIC WATER LEVEL: 0 m.
DYNAMIC WATER LEVEL:

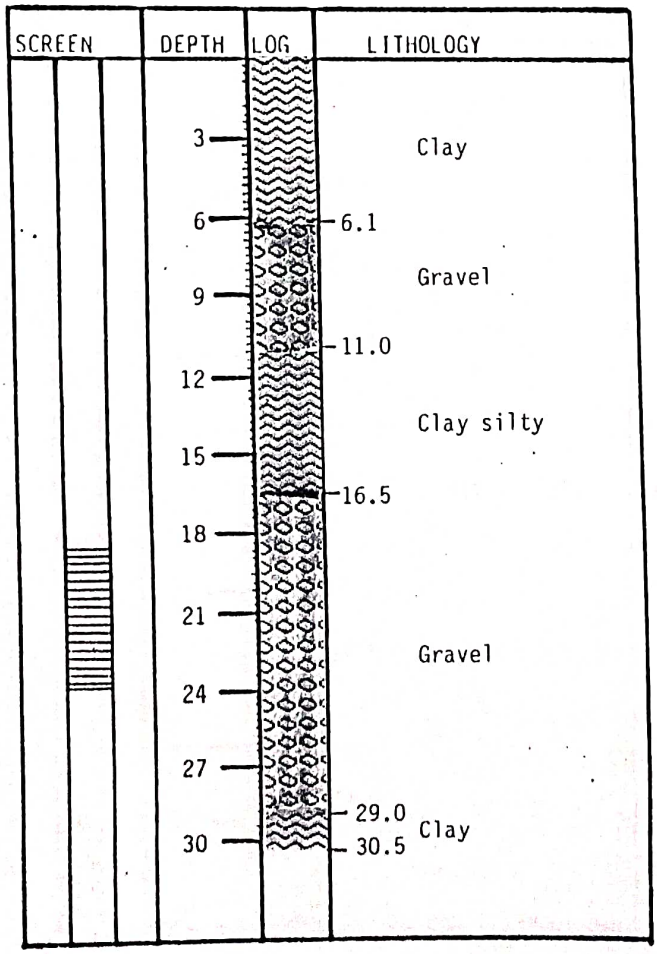
COMMENTS:

APPENDIX 3/12

DANG DISTRICT (DEUKHURI VALLEY)

WELL NO. GW5	LOCATION Sundabari
ELEVATION 261.93 m	X = 657413 Y = 3082531
METHOD OF DRILLING	Rig
DRILLING DATES	23/04/87 - 25/04/87
TOTAL DEPTH	30.5 m.
COMMENTS	Screen Position: 18.3 - 23.8 m. Screen Type : Slotted Pipe M.P: 0.14m. Well Size : 4"

WELL LOG



PUMPING TEST

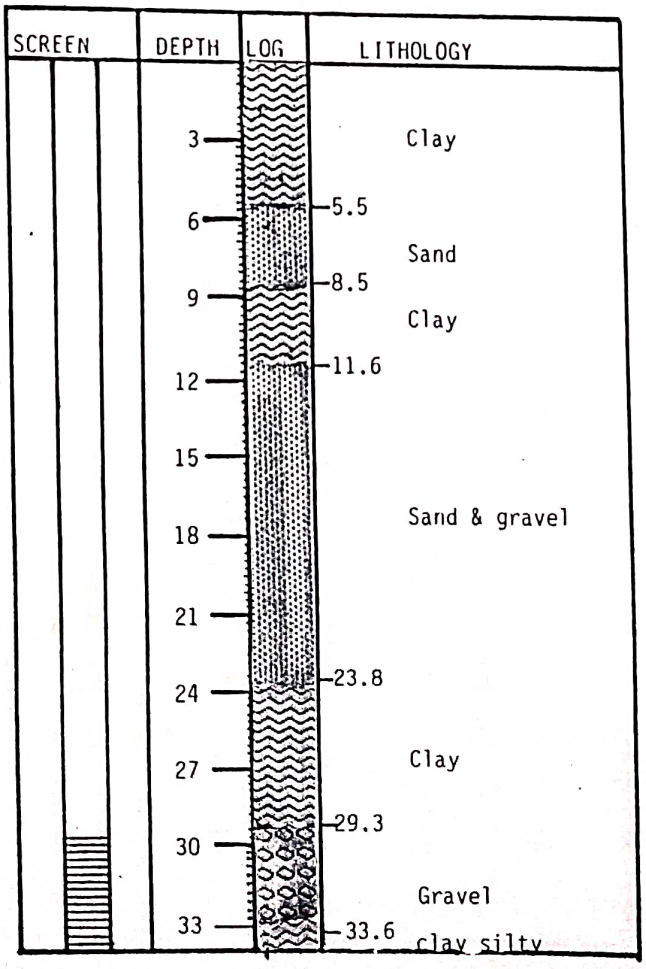
DATE:
Q(l/s):
DURATION:
TRANSMISSIVITY: m^2/day
METHOD:
STORAGE COEFFICIENT:
STATIC WATER LEVEL: 6.55 m.
DYNAMIC WATER LEVEL:

COMMENTS:

DANG DISTRICT (DEUKHURI VALLEY)

WELL NO. GW6	LOCATION Phalkapur(N)
ELEVATION 261.92 m	X = 654891 Y = 3082679
METHOD OF DRILLING	Rig
DRILLING DATES	26/04/87 - 28/04/87
TOTAL DEPTH	35.4 m.
COMMENTS	Screen Position: 29.7 - 35.2 m. Screen Type : Slotted Pipe Well Size : 4" M.P: 0.52 m.

WELL LOG



PUMPING TEST

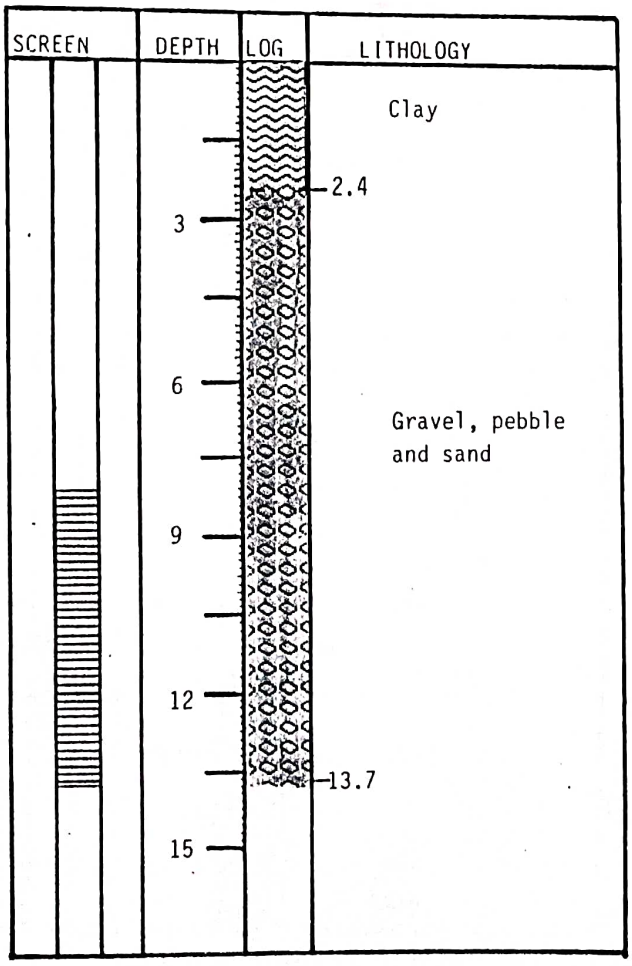
DATE:
Q(l/s):
DURATION:
TRANSMISSIVITY: m^2/day
METHOD:
STORAGE COEFFICIENT:
STATIC WATER LEVEL: 11.70 m.
DYNAMIC WATER LEVEL:

COMMENTS:

DANG DISTRICT (DEUKHURI VALLEY)

WELL NO. GW7	LOCATION Sisaniya
ELEVATION 268.18 m	X = 562625 Y = 3080700
METHOD OF DRILLING	Rig
DRILLING DATES	05/05/87 - 08/05/87
TOTAL DEPTH	13.7 m.
COMMENTS	Screen Position: 8.1 - 13.6 m. Screen Type : Slotted Pipe Well Size : 4" M.P: 0.63 m.

WELL LOG



PUMPING TEST

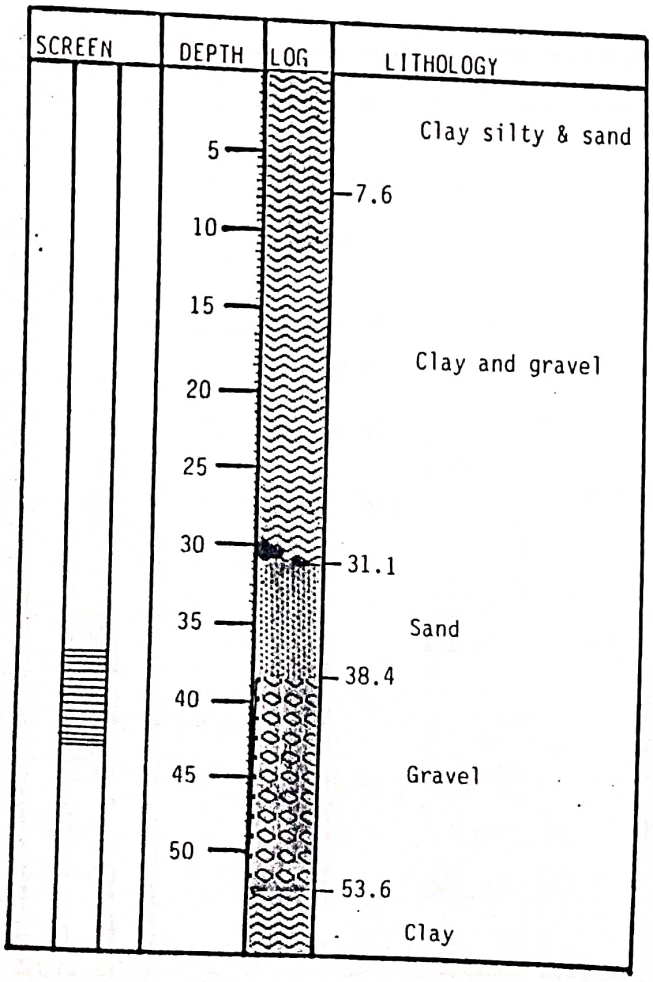
DATE:
Q(l/s):
DURATION:
TRANSMISSIVITY: m^2/day
METHOD:
STORAGE COEFFICIENT:
STATIC WATER LEVEL: 2.0 m.
DYNAMIC WATER LEVEL:

COMMENTS:

DANG DISTRICT (DEUKHURI VALLEY)

WELL NO. GW8	LOCATION Kolahi
ELEVATION 251.27 m	X = 649654 Y = 3082448
METHOD OF DRILLING	Rig
DRILLING DATES	15/05/87 - 19/05/87
TOTAL DEPTH	56.7 m.
COMMENTS	M.P: 0.54 m. Screen Position: 37.2 - 42.7 m. Screen Type : Slotted Pipe Well Size : 6"

WELL LOG



PUMPING TEST

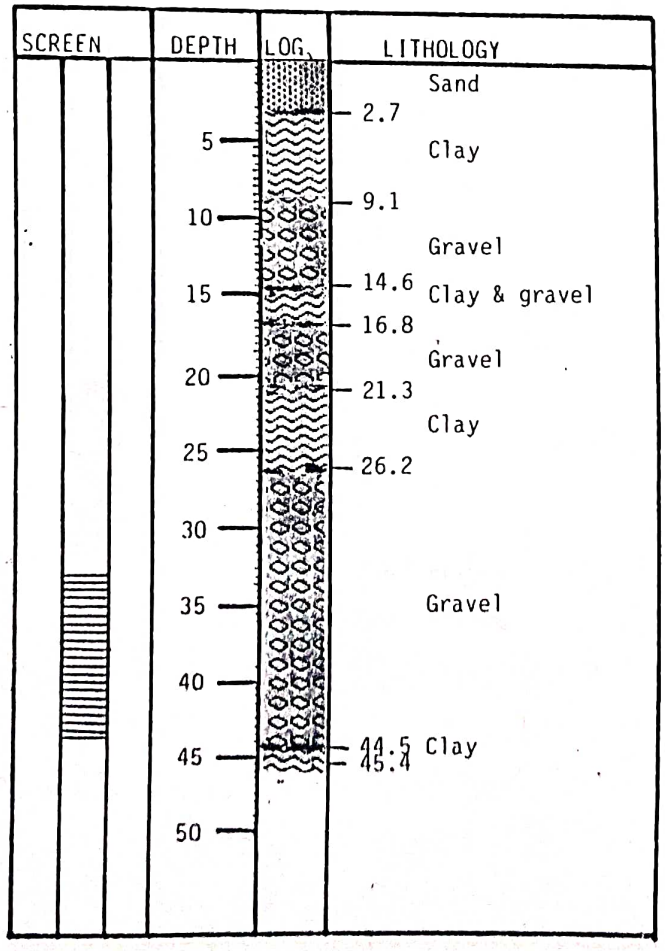
DATE:
Q(l/s):
DURATION:
TRANSMISSIVITY: m^2/day
METHOD:
STORAGE COEFFICIENT:
STATIC WATER LEVEL: 9.50 m.
DYNAMIC WATER LEVEL:

COMMENTS:

DANG DISTRICT (DEUKHURI VALLEY)

WELL NO. GW9	LOCATION Phalkapur(S)
ELEVATION 258.48 m	X = 654500 Y = 3081750
METHOD OF DRILLING	Rig
DRILLING DATES	22/05/87 - 01/06/87
TOTAL DEPTH	45.4 m.
COMMENTS	Screen Position: 32.9 - 43.9 m. Screen Type : Slotted Pipe Well Size : 4" M.P: 0.45 m.

WELL LOG



PUMPING TEST

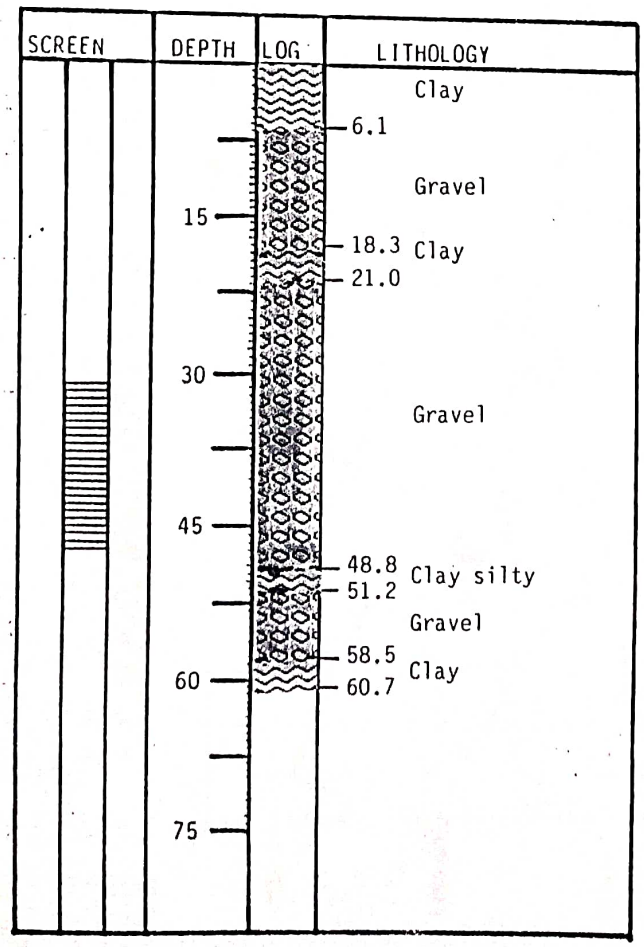
DATE:
Q(l/s):
DURATION:
TRANSMISSIVITY: m^2/day
METHOD:
STORAGE COEFFICIENT:
STATIC WATER LEVEL: 9.0 m.
DYNAMIC WATER LEVEL:

COMMENTS:

DANG DISTRICT (DEUKHURI VALLEY)

WELL NO. GW10	LOCATION Narti(S)
ELEVATION 261.34 m	X = 658625 Y = 3081500
METHOD OF DRILLING	Rig
DRILLING DATES	21/05/87 - 03/06/87
TOTAL DEPTH	60.7 m.
COMMENTS	Screen Position: 30.8 - 47.4 m. Screen Type : Slotted Pipe Well Size : 10"/6" M.P: 0.32 m.

WELL LOG

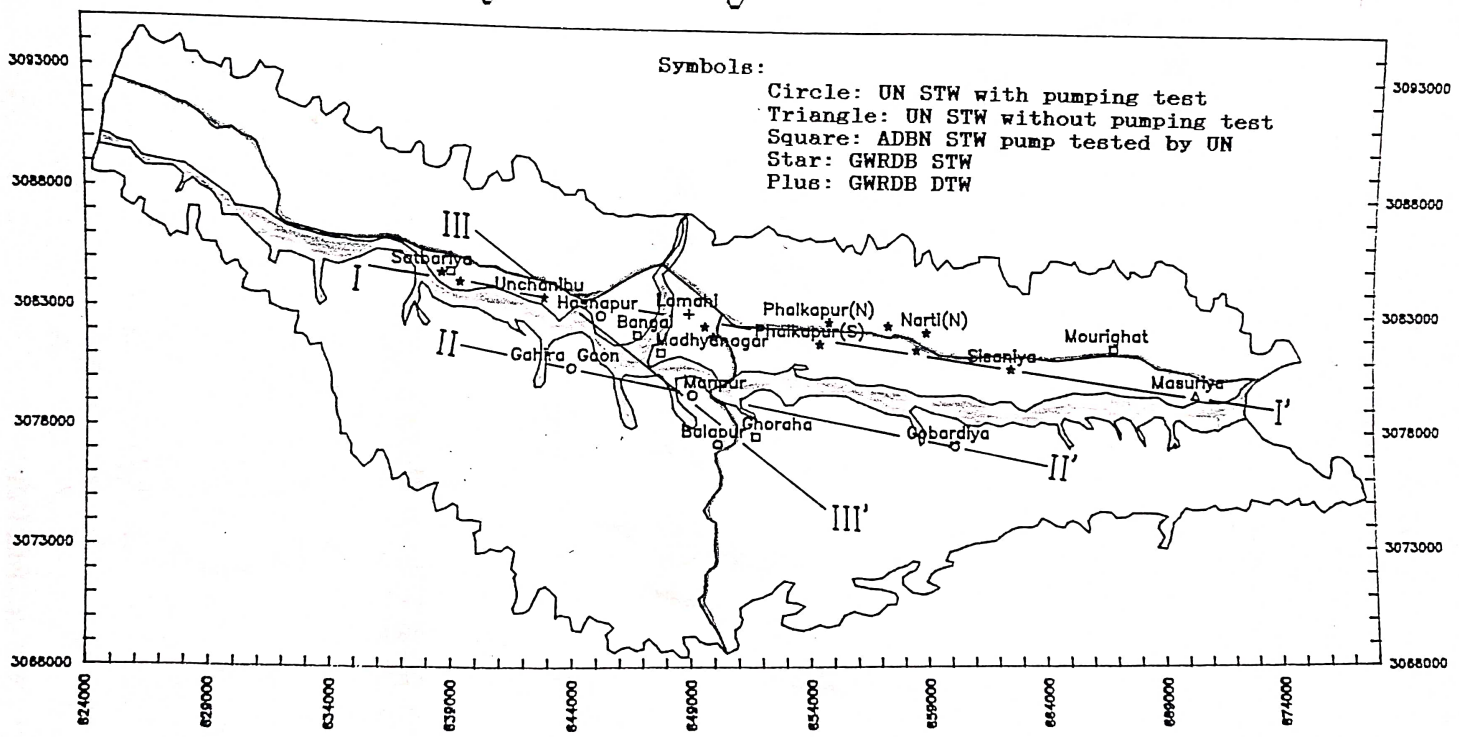


PUMPING TEST

DATE:
Q(l/s):
DURATION:
TRANSMISSIVITY: m^2/day
METHOD:
STORAGE COEFFICIENT:
STATIC WATER LEVEL: 4.50 m.
DYNAMIC WATER LEVEL:

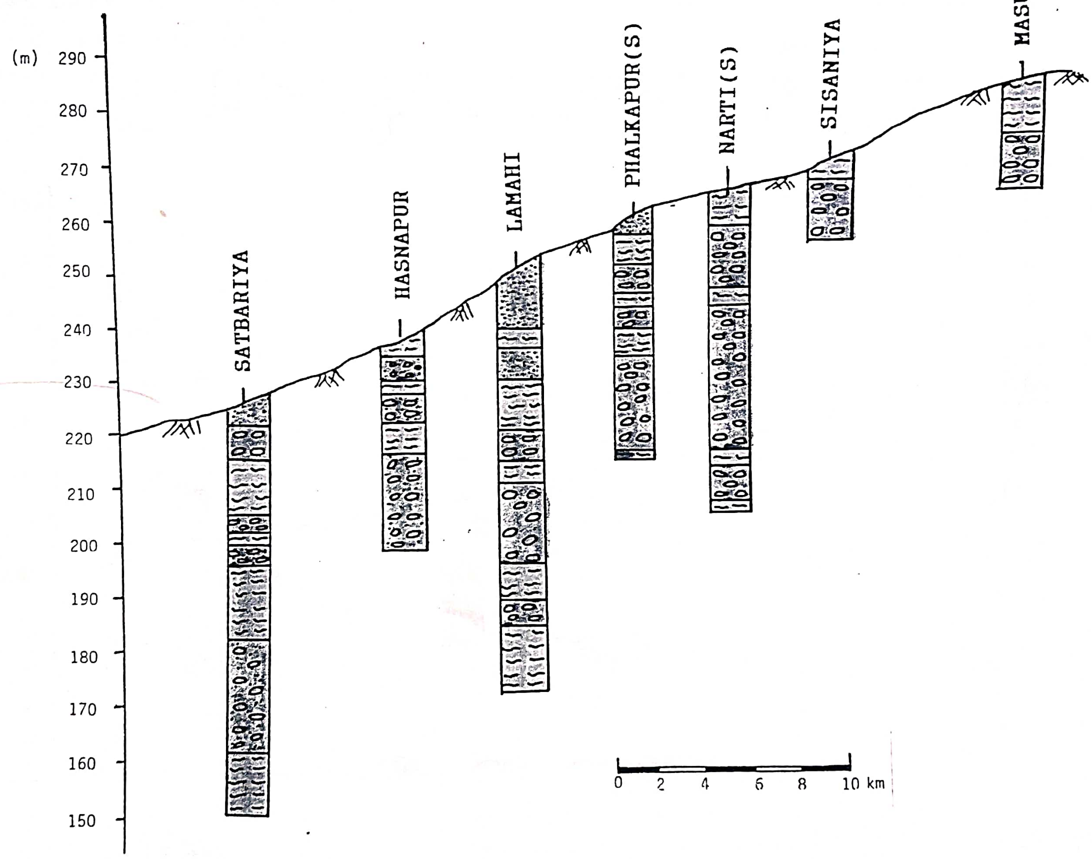
COMMENTS:

DEUKHURI VALLEY - LITHOLOGICAL CROSS SECTIONS I - III



APPENDIX 4/1

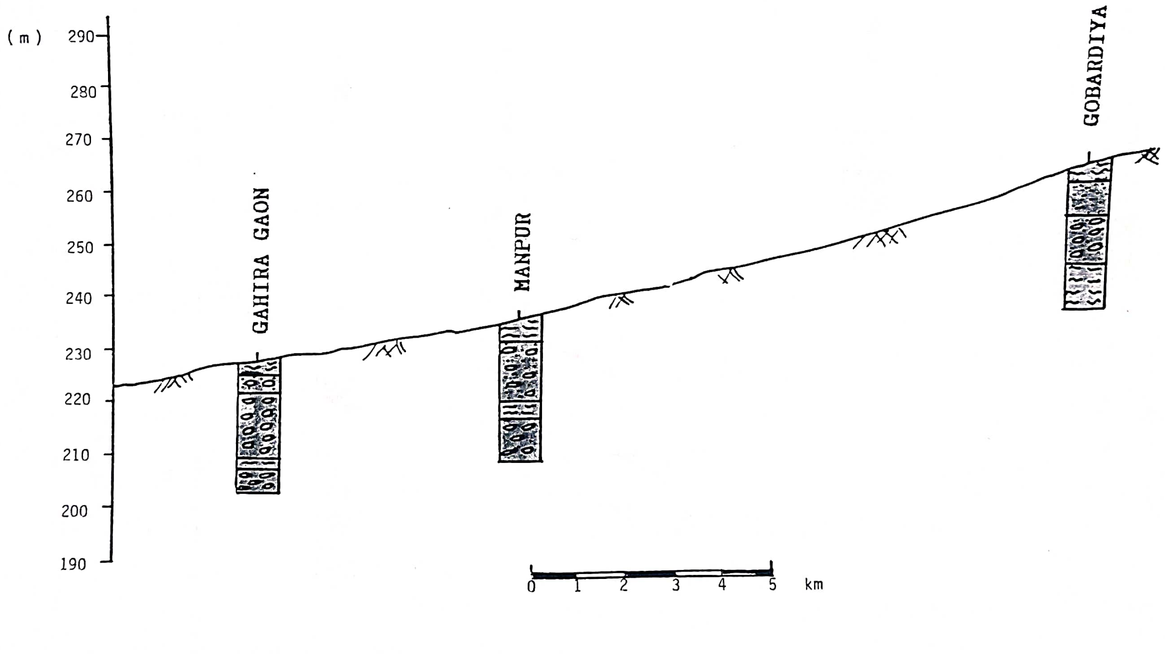
LITHOLOGICAL CROSS SECTION I - I'



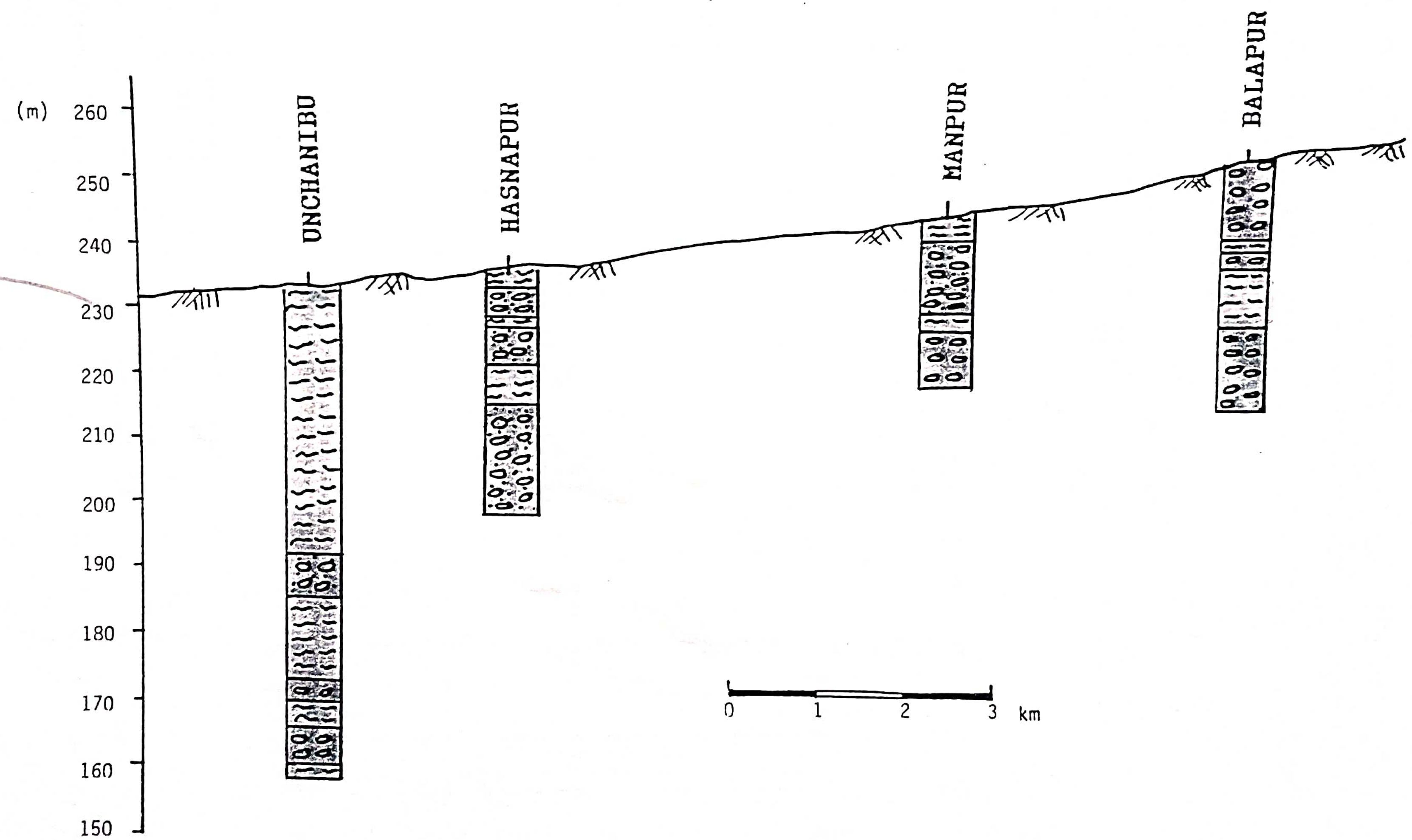
APPENDIX 4/2

APPENDIX 4/3

LITHOLOGICAL CROSS SECTION II-II'



LITHOLOGICAL CROSS SECTION III - III'



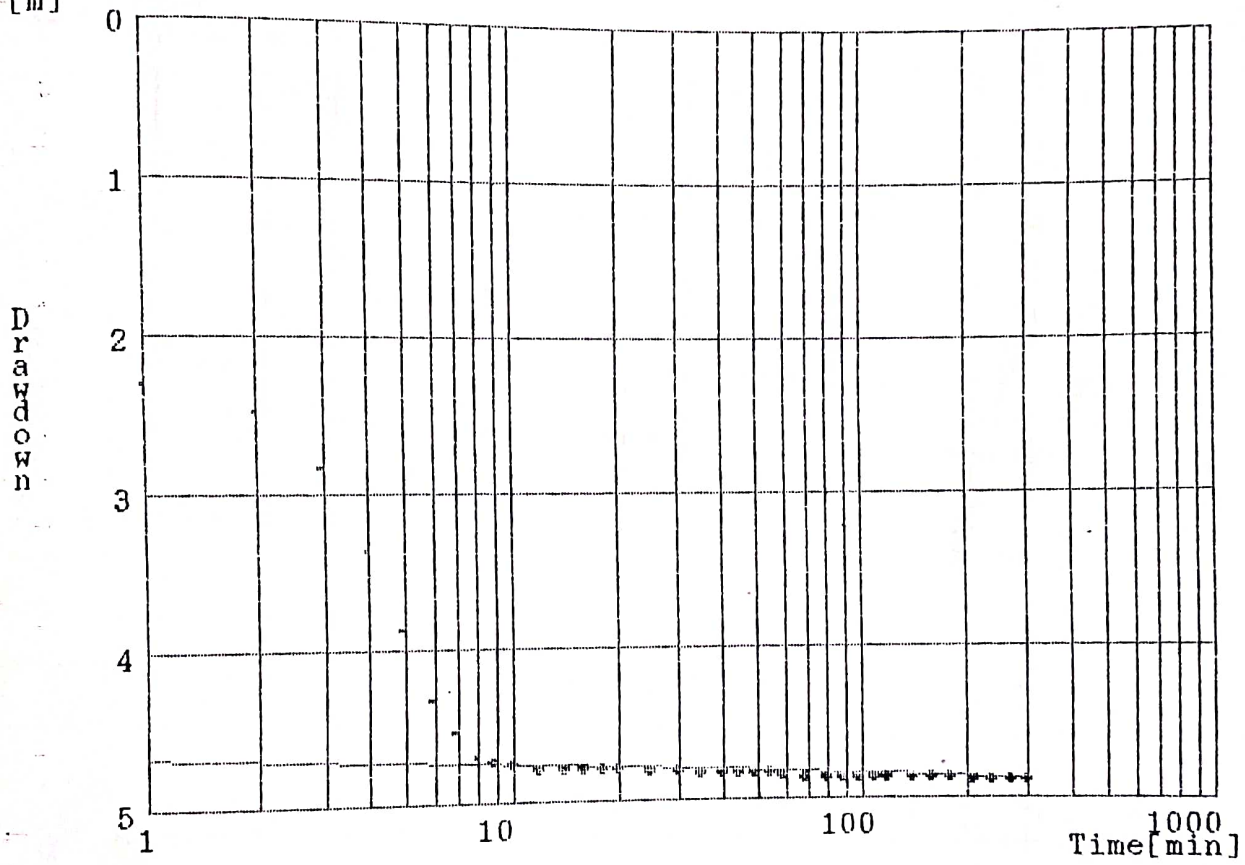
APPENDIX 4/4

Project : NEP/86/025 (DANG)
Organization : UNDP/GWRDB

Test : DKSTW 1 HASNAPUR

Constant Pumping Rate = 23.000 [l/s]
Distance from Pumping Well = 0.05 [m]
Type of Aquifer = CONFINED
Type of Input Data = LEVEL
Static Water Level = -2.43 [m]
Well Type = STANDARD

JACOB METHOD



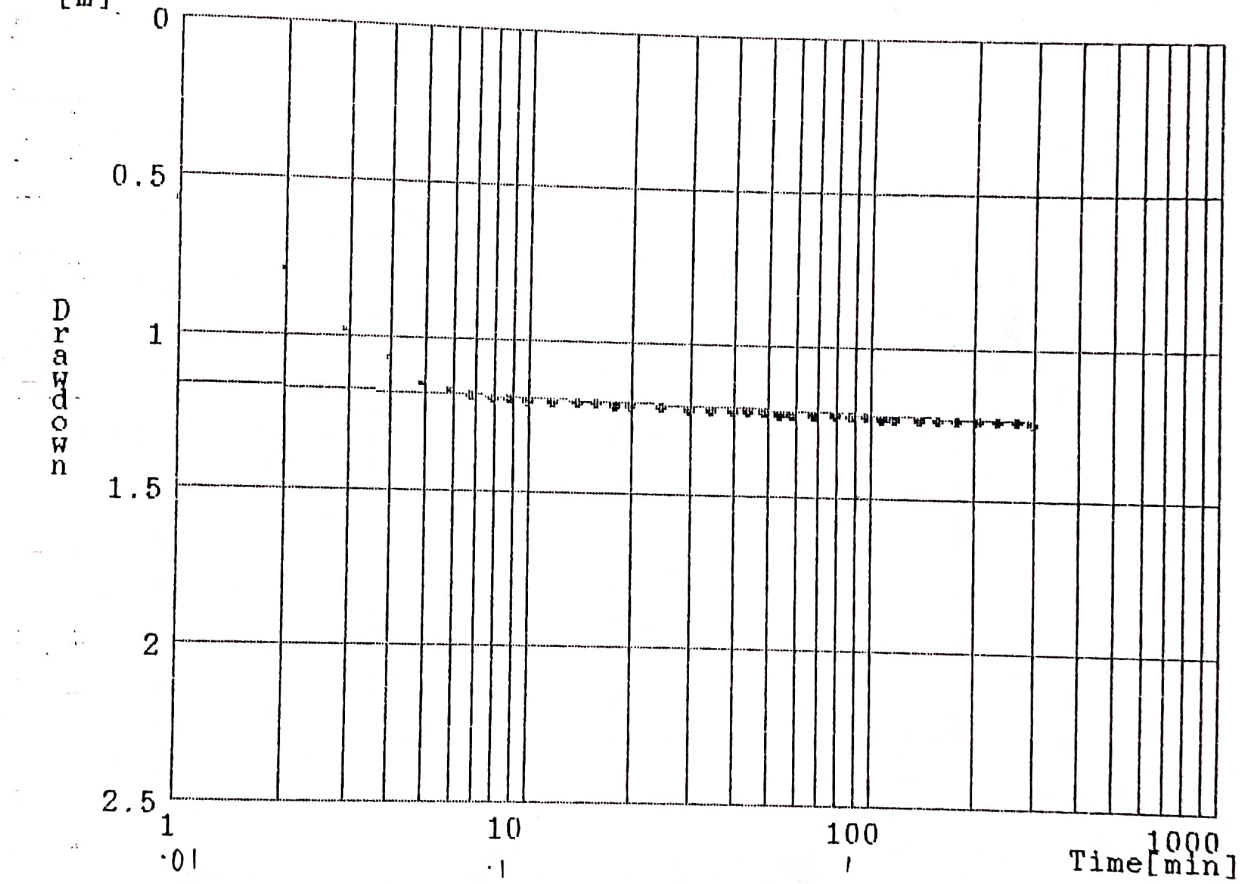
Transmissivity = 4608. [m2/day]
Storage Coefficient = 0.00000000
Standard Deviation = 0.0084 [m]
A0 = 0.468084E+01
A1 = 0.789113E-01
Number of Points = 28 of 36

Project : NEP/86/025 (DANG)
Organization : UNDP/GWRDB

Test : DKSTW 2 GAHIRA GAON

Constant Pumping Rate = 22.000 [l/s]
Distance from Pumping Well = 0.05 [m]
Type of Aquifer = UNCONFINED
Initial Saturated Thickness = 20.00 [m]
Type of Input Data = LEVEL
Static Water Level = -6.57 [m]
Well Type = STANDARD

JACOB METHOD



Transmissivity = 10576. [m2/day]
Storage Coefficient = 0.00000000
Standard Deviation = 0.0030 [m]
A0 = 0.115497E+01
A1 = 0.328902E-01
Number of Points = 30 of 36

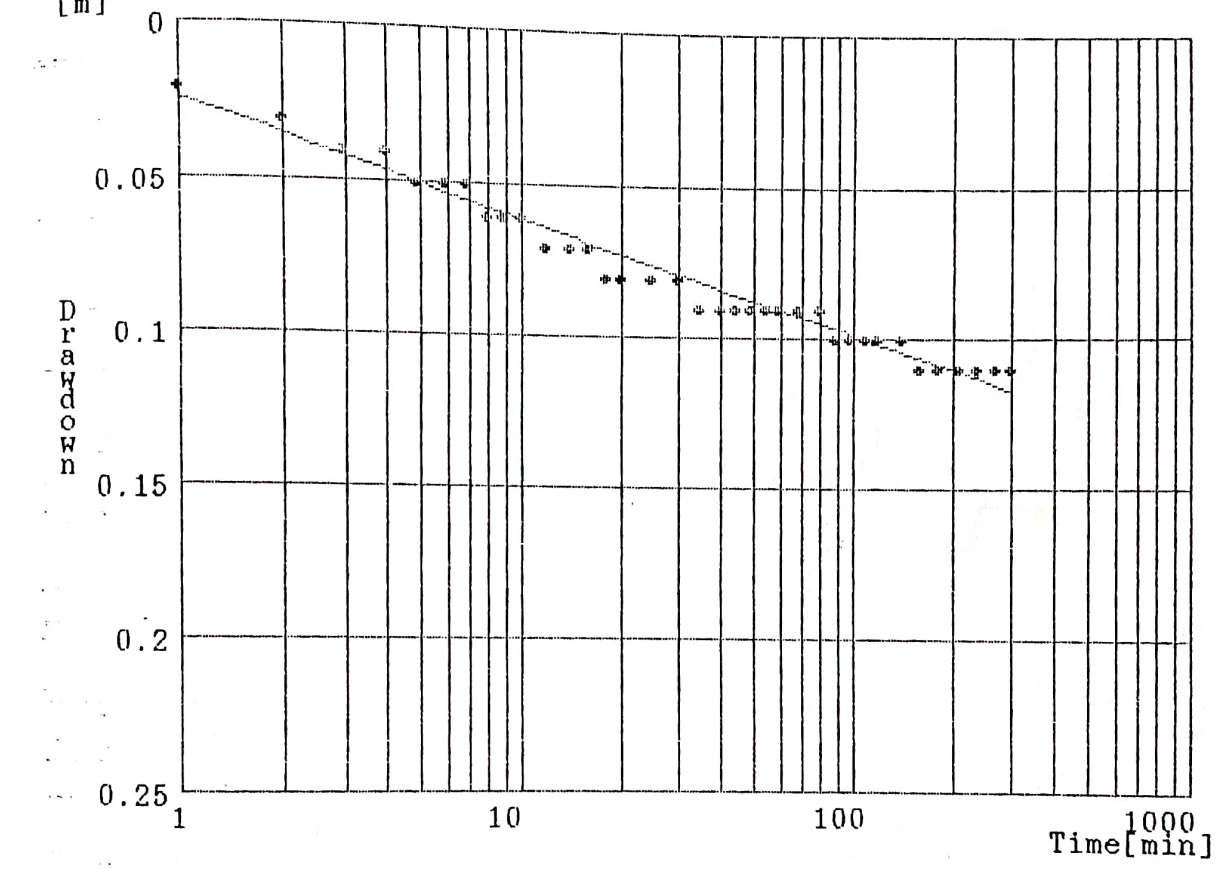
APPENDIX 5/2A

Project : NEP/86/025 (DANG)
Organization : UNDP/GWRDB

Test : DKSTW 2 GAHIRA GAON (OBS.WELL)

Constant Pumping Rate = 22.000 [l/s]
Distance from Pumping Well = 129.00 [m]
Type of Aquifer = UNCONFINED
Initial Saturated Thickness = 20.00 [m]
Type of Input Data = LEVEL
Static Water Level = -6.38 [m]
Well Type = STANDARD

JACOB METHOD

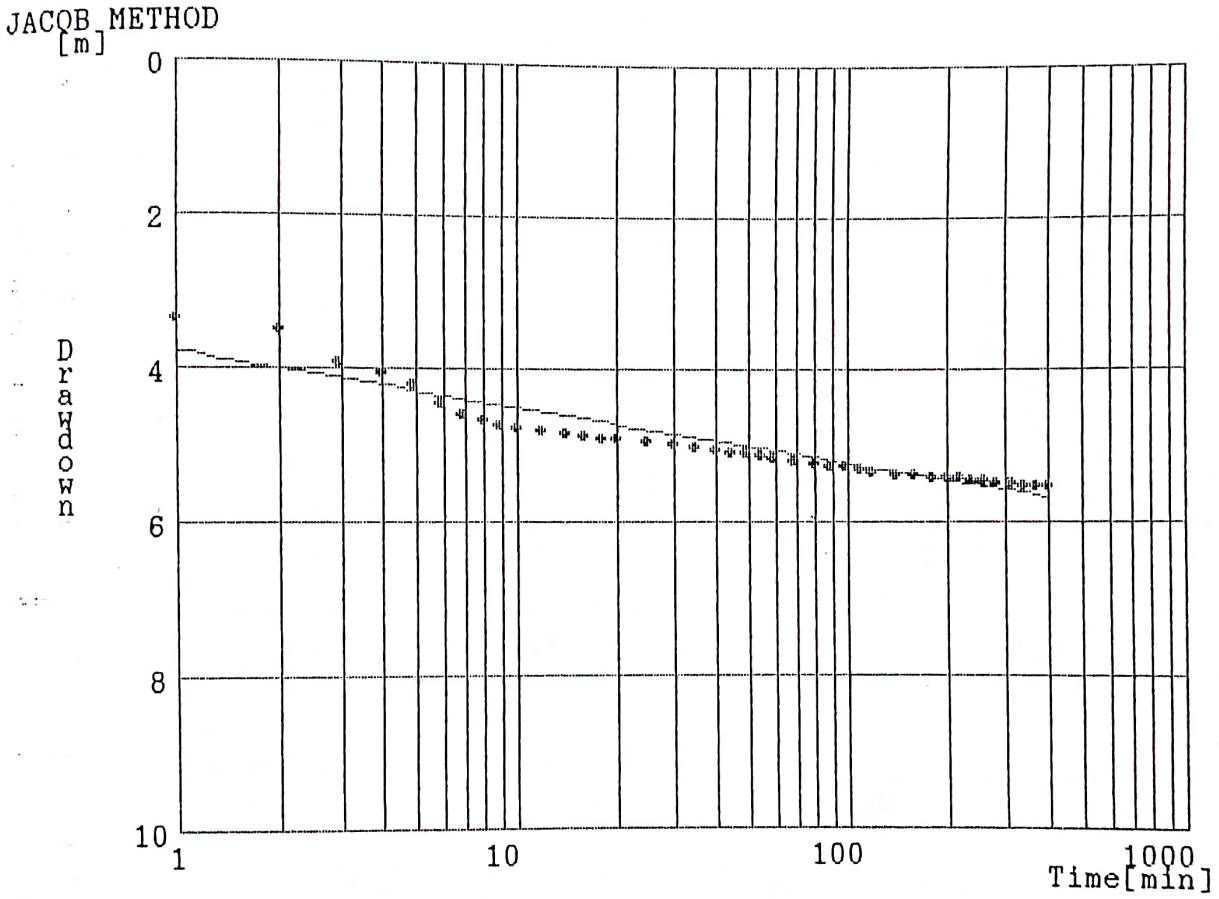


Transmissivity = 9270. [m2/day]
Storage Coefficient = 0.00020226
Standard Deviation = 0.0041 [m]
A0 = 0.238098E-01
A1 = 0.375224E-01
Number of Points = 36 of 36

Project : NEP/86/025 (DANG)
Organization : UNDP/GWRDB

Test : DKSTW 3 MANPUR

Constant Pumping Rate = 22.000 [l/s]
Distance from Pumping Well = 0.05 [m]
Type of Aquifer = CONFINED
Type of Input Data = LEVEL
Static Water Level = -2.39 [m]
Well Type = STANDARD



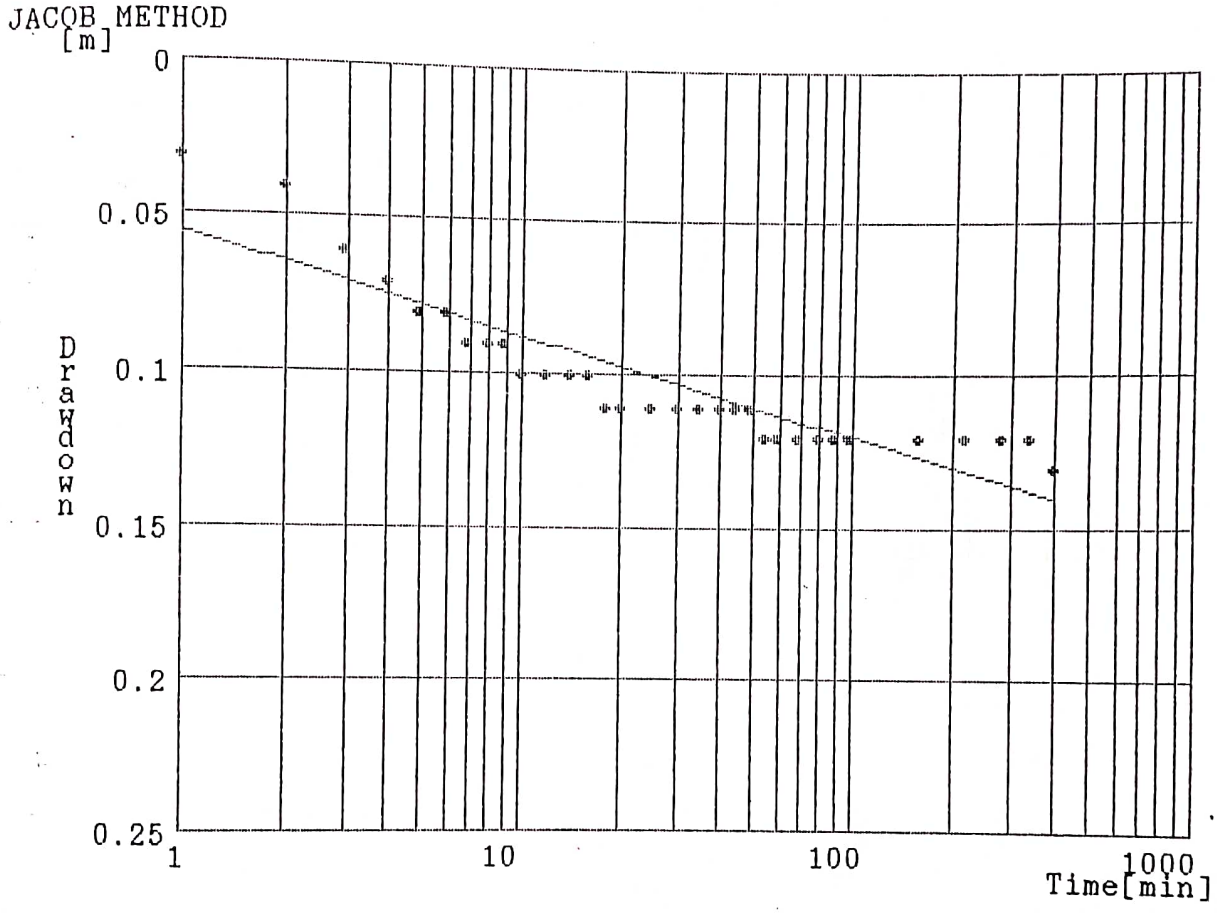
Transmissivity = 477. [m2/day]
Storage Coefficient =
Standard Deviation = 0.1703 [m]
A0 = 0.376548E+01
A1 = 0.729937E+00
Number of Points = 41 of 41

APPENDIX 5/3A

Project : NEP/86/025 (DANG)
Organization : UNDP/GWRDB

Test : DKSTW 3 MANPUR (OBS.WELL)

Constant Pumping Rate = 22.000 [l/s]
Distance from Pumping Well = 149.00 [m]
Type of Aquifer = CONFINED
Type of Input Data = LEVEL
Static Water Level = -3.18 [m]
Well Type = STANDARD



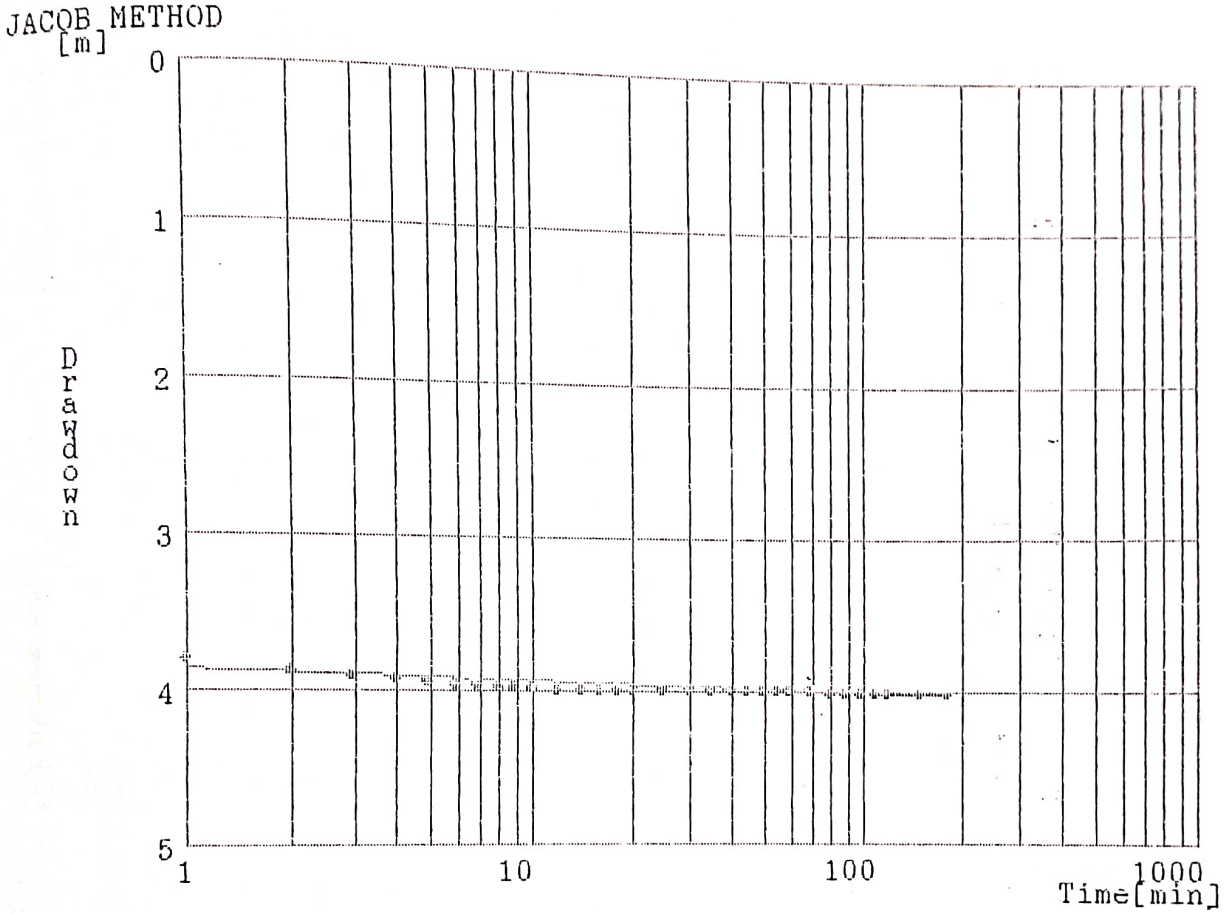
Transmissivity = 10682. [m2/day]
Storage Coefficient = 0.00001525
Standard Deviation = 0.0101 [m]
A0 = 0.551850E-01
A1 = 0.325640E-01
Number of Points = 32 of 32

APPENDIX 5/3B

Project : NEP/86/025 (DANG)
Organization : UNDP/GWRDB

Test : DKSTW 4 BALAPUR

Constant Pumping Rate = 7.000 [l/s]
Distance from Pumping Well = 0.05 [m]
Type of Aquifer = CONFINED
Type of Input Data = LEVEL
Static Water Level = -5.11 [m]
Well Type = STANDARD



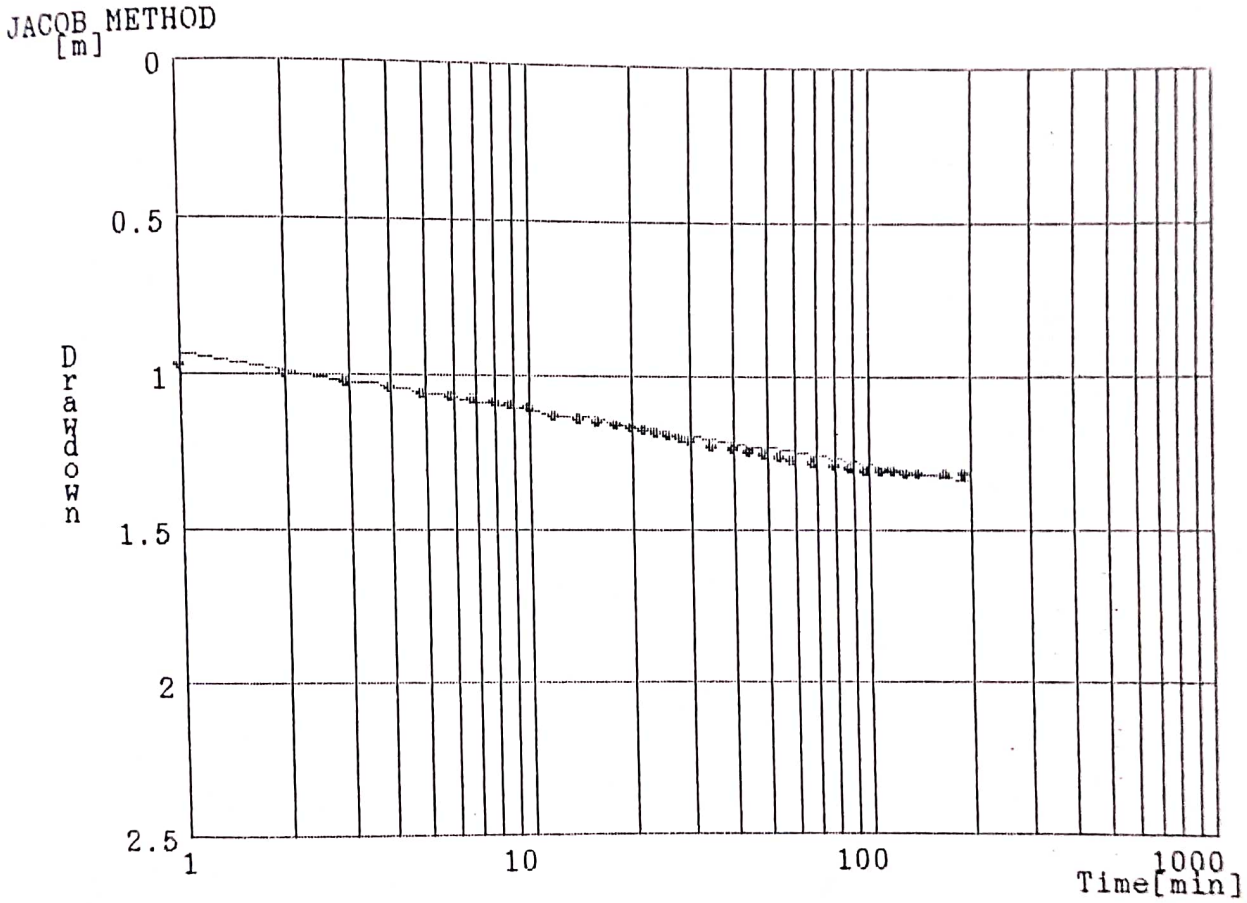
Transmissivity = 1584. [m2/day]
Storage Coefficient = 0.00000000
Standard Deviation = 0.0242 [m]
A0 = 0.386313E+01
A1 = 0.698661E-01
Number of Points = 31 of 31

APPENDIX 5/4

Project : NEP/86/025 (DANG)
Organization : UNDP/GWRDB

Test : DKSTW 5 GOBARDIYA

Constant Pumping Rate = 11.000 [l/s]
Distance from Pumping Well = 0.05 [m]
Type of Aquifer = UNCONFINED
Initial Saturated Thickness = 12.78 [m]
Type of Input Data = LEVEL
Static Water Level = -6.58 [m]
Well Type = STANDARD



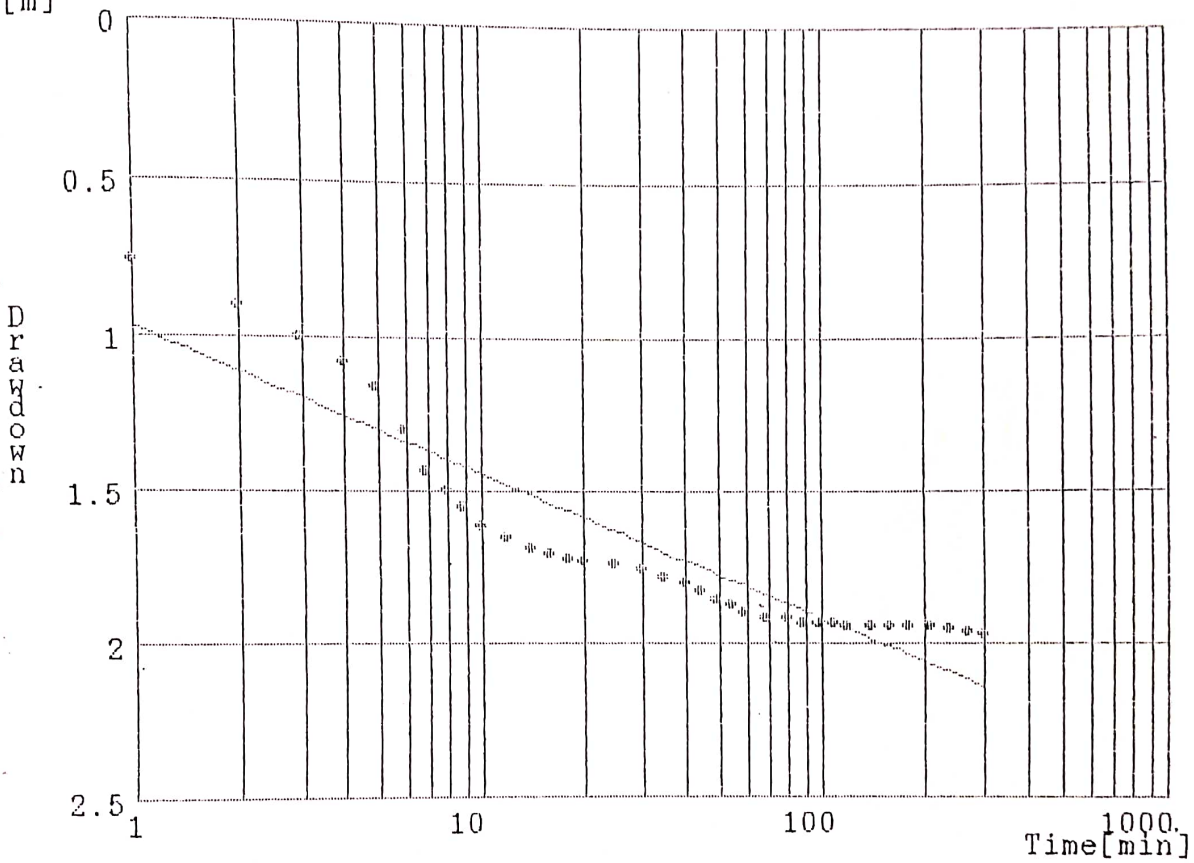
Transmissivity = 989. [m2/day]
Storage Coefficient = 0.00311151
Standard Deviation = 0.0113 [m]
A0 = 0.932552E+00
A1 = 0.175815E+00
Number of Points = 36 of 36

Project : NEP/86/025 (DANG)
Organization : UNDP/GWRDB

Test : DKSTW (ADBN) SATBARIYA

Constant Pumping Rate = 21.000 [l/s]
Distance from Observation Well = 0.05 [m]
Type of Aquifer = CONFINED
Type of Input Data = LEVEL
Static Water Level = -4.21 [m]
Well Type = STANDARD

JACOB METHOD



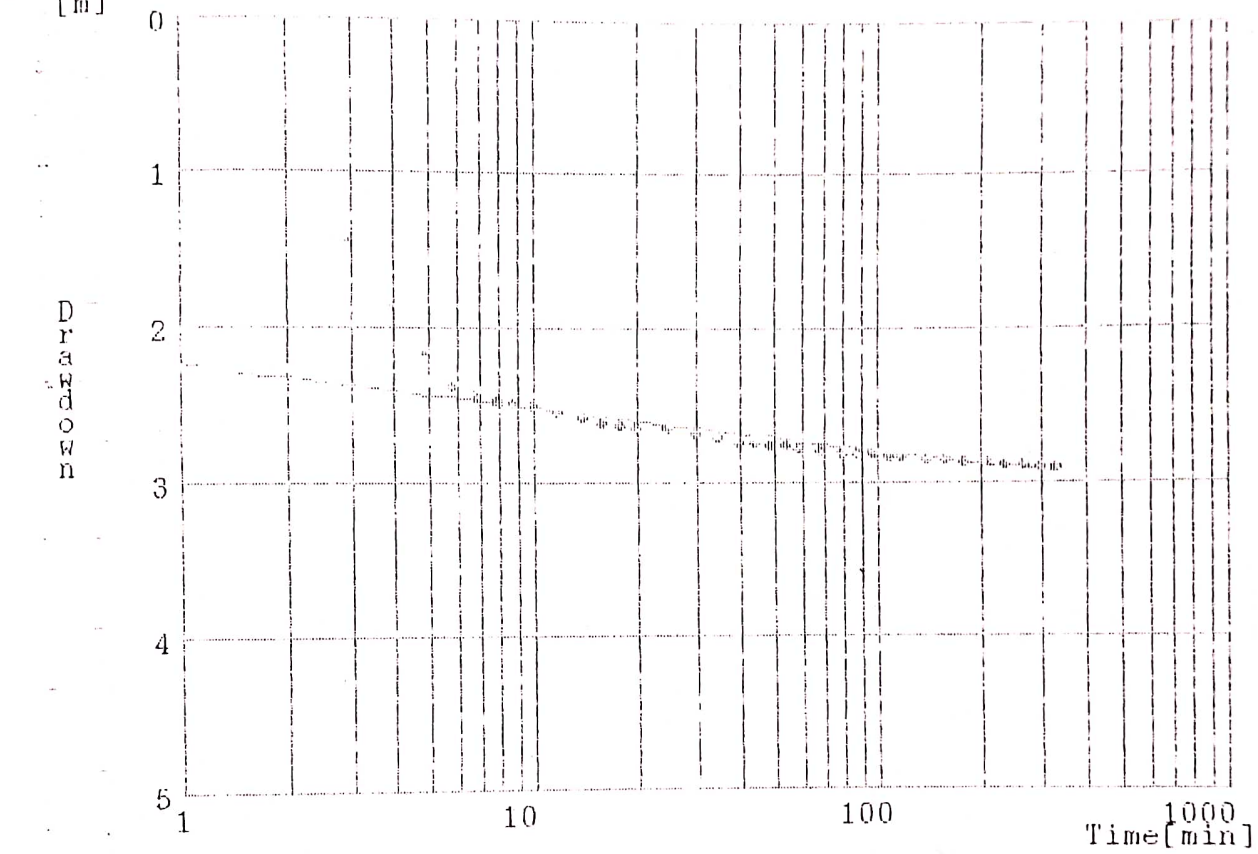
Transmissivity = 700. [m2/day]
Storage Coefficient =
Standard Deviation = 0.121987E+00 [m]
A0 = 0.967426E+00
A1 = 0.474087E+00
Number of Points = 36 of 36

Project : NEP/86/025 (DANG)
Organisation : UNDP/GWRDB

Test : DKSTW (ADBN) BANGAI

Constant Pumping Rate = 21.000 [l/s]
Distance from Pumping Well = 0.05 [m]
Type of Aquifer = CONFINED
Type of Input Data = LEVEL
Static Water Level = -3.78 [m]
Well Type = STANDARD

JACOB METHOD



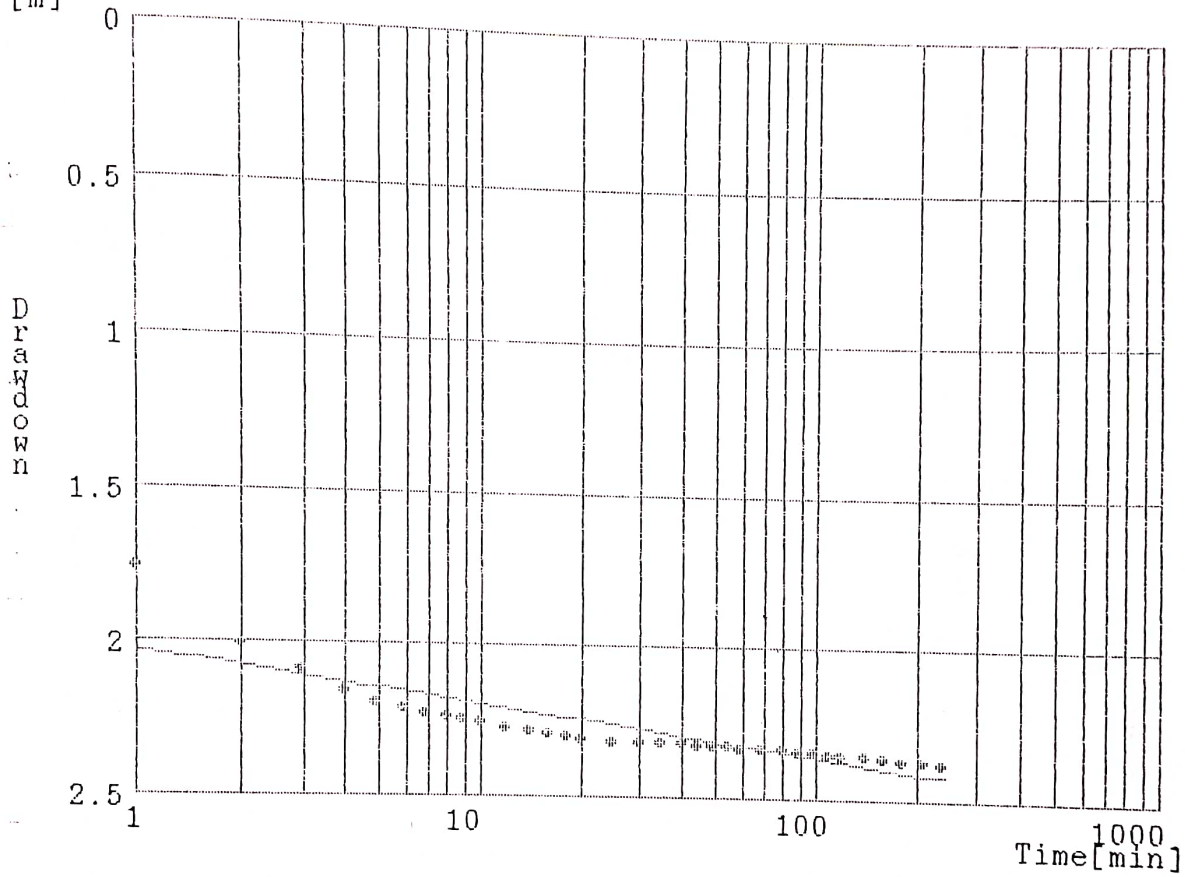
Transmissivity = 1217. [m2/day]
Storage Coefficient = 0.00000
Standard Deviation = 0.0322 [m]
A0 = 0.224299E+01
A1 = 0.272911E+00
Number of Points = 32 of 37

Project : NEP/86/025 (DANG)
Organization : UNDP/GWRDB

Test : DKSTW (ADBN) MADHYA NAGAR

Constant Pumping Rate = 19.000 [l/s]
Distance from Observation Well = 0.05 [m]
Type of Aquifer = CONFINED
Type of Input Data = LEVEL
Static Water Level = -5.40 [m]
Well Type = STANDARD

JACOB METHOD



Transmissivity = 1795. [m2/day]
Storage Coefficient = 0.00000000
Standard Deviation = 0.621143E-01 [m]
A0 = 0.202565E+01
A1 = 0.167353E+00
Number of Points = 34 of 34

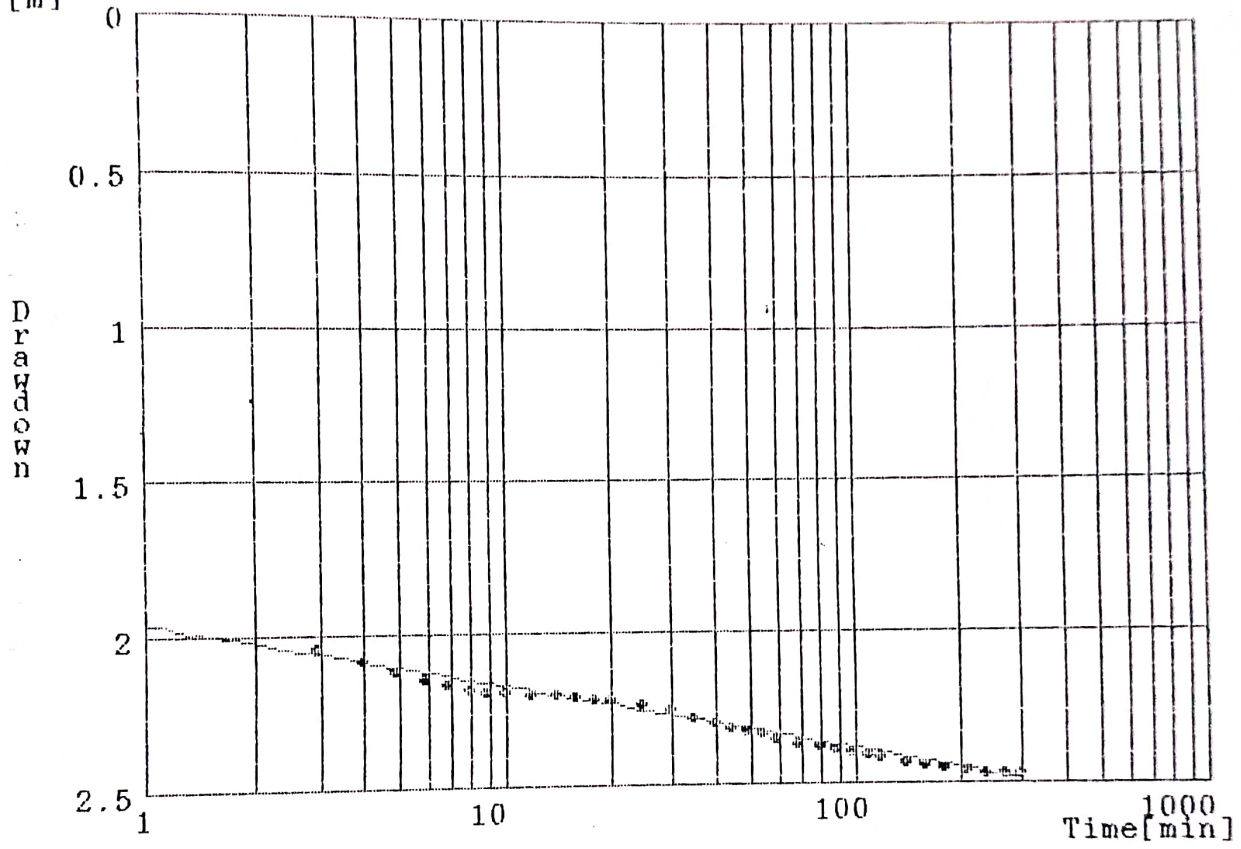
APPENDIX 5/8

Project : NEP/86/025 (DANG)
Organization : UNDP/GWRDB

Test : DKSTW (ADBN) GHORAHA

Constant Pumping Rate = 20.000 [l/s]
Distance from Pumping Well = 0.05 [m]
Type of Aquifer = CONFINED
Type of Input Data = LEVEL
Static Water Level = -3.07 [m]
Well Type = STANDARD

JACOB METHOD



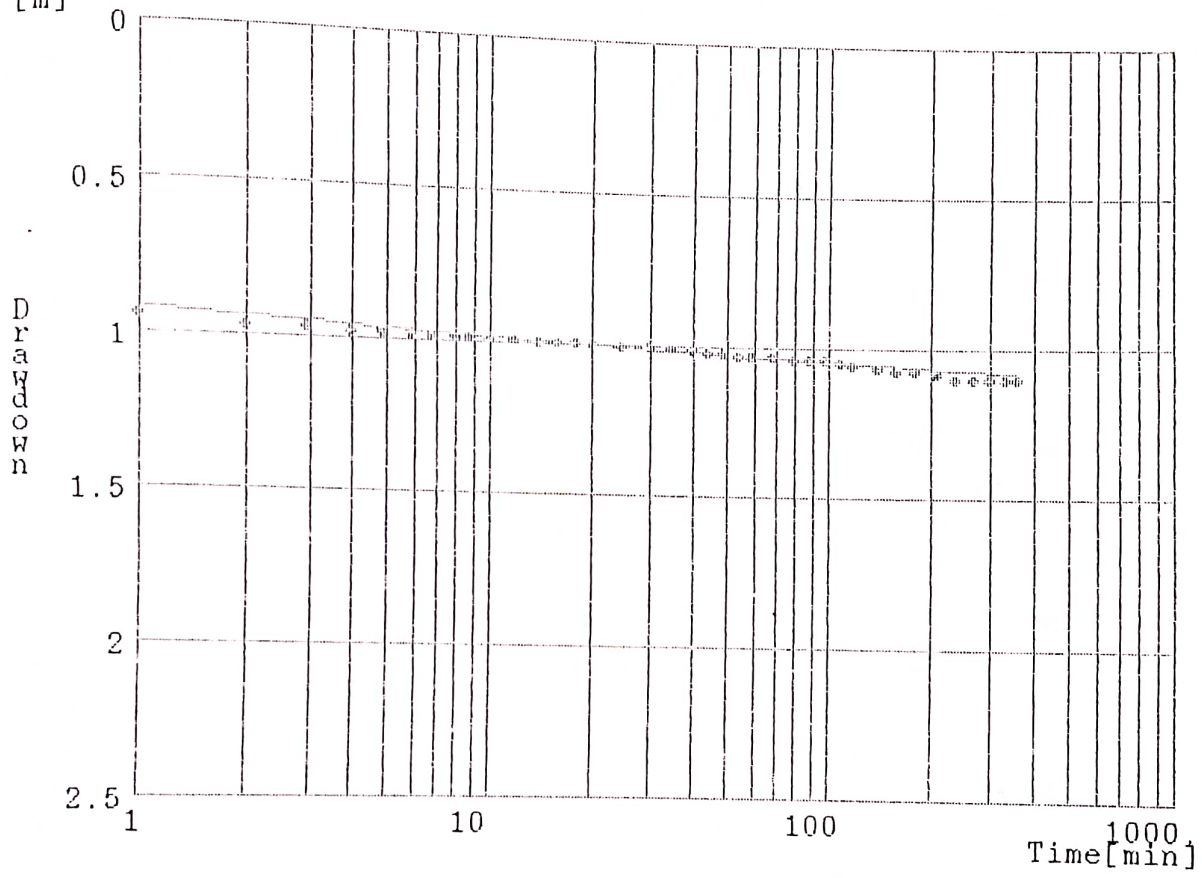
Transmissivity = 1494. [m2/day]
Storage Coefficient = 0.000000
Standard Deviation = 0.0137 [m]
A0 = 0.195777E+01
A1 = 0.211669E+00
Number of Points = 34 of 36

Project : NEP/86/025 (DANG)
Organization : UNDP/GWRDB

Test : DKSTW (ADBN) MOURIGHAT

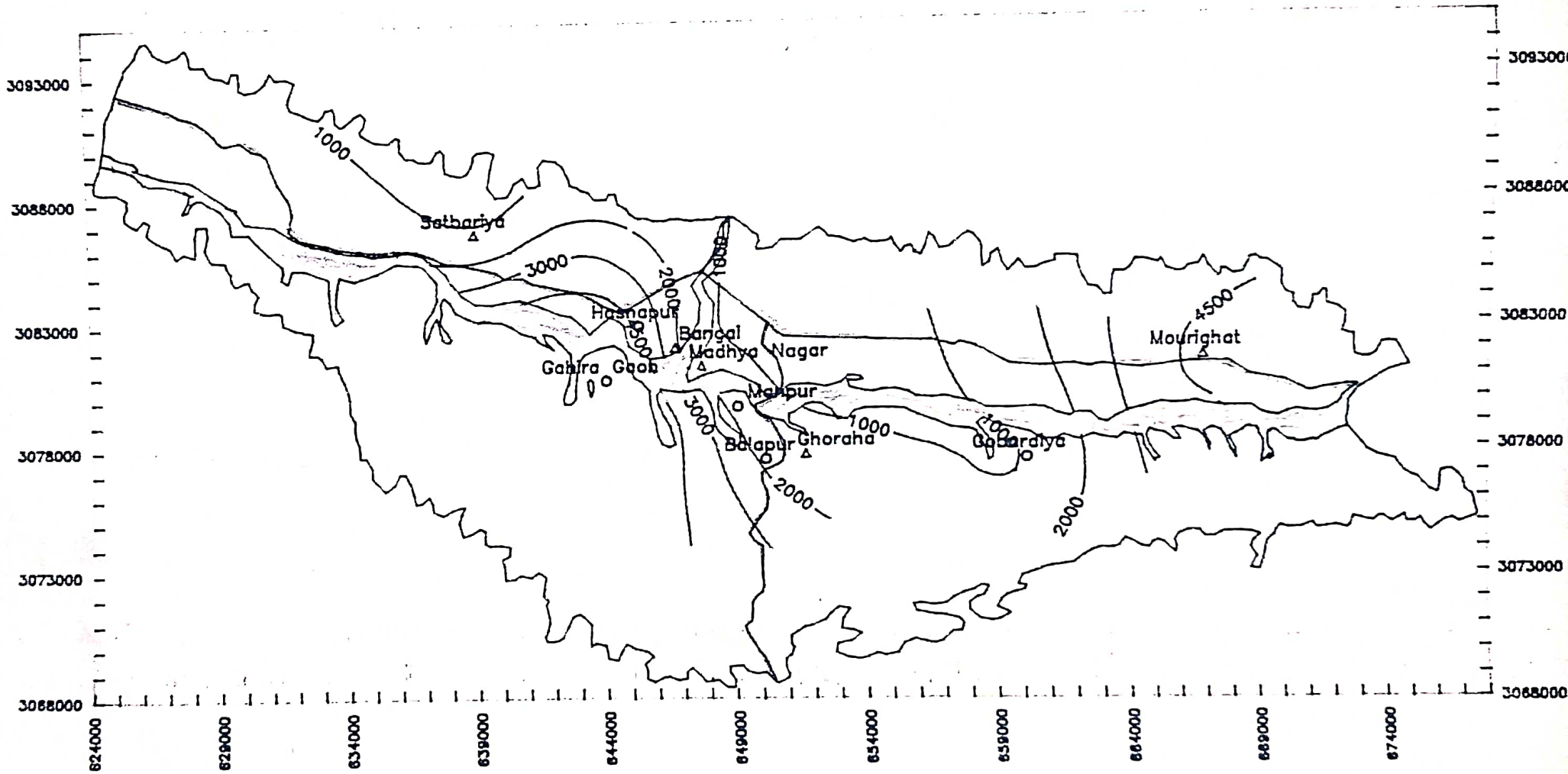
Constant Pumping Rate = 20.000 [l/s]
Distance from Observation Well = 0.05 [m]
Type of Aquifer = CONFINED
Type of Input Data = LEVEL
Static Water Level = -6.62 [m]
Well Type = STANDARD

JACOB METHOD



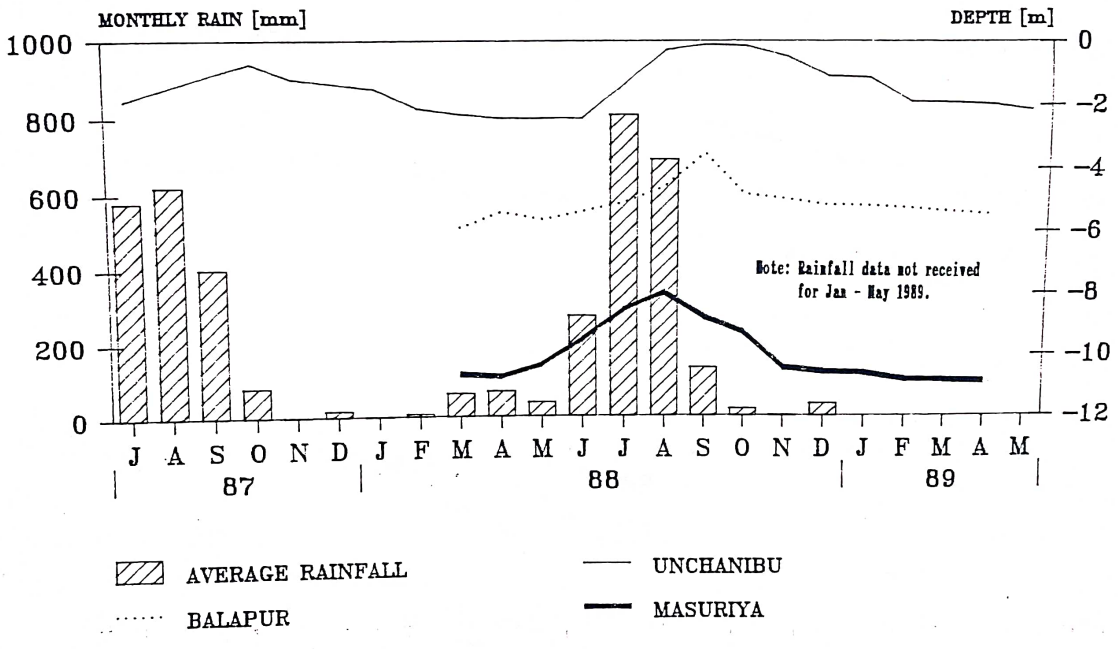
Transmissivity = 4928. [m2/day]
Storage Coefficient = 0.00000000
Standard Deviation = 0.111485E-01 [m]
A0 = 0.916784E+00
A1 = 0.641693E-01
Number of Points = 38 of 38

DEUKHURI VALLEY – TRANSMISSIVITIES (M2/DAY)



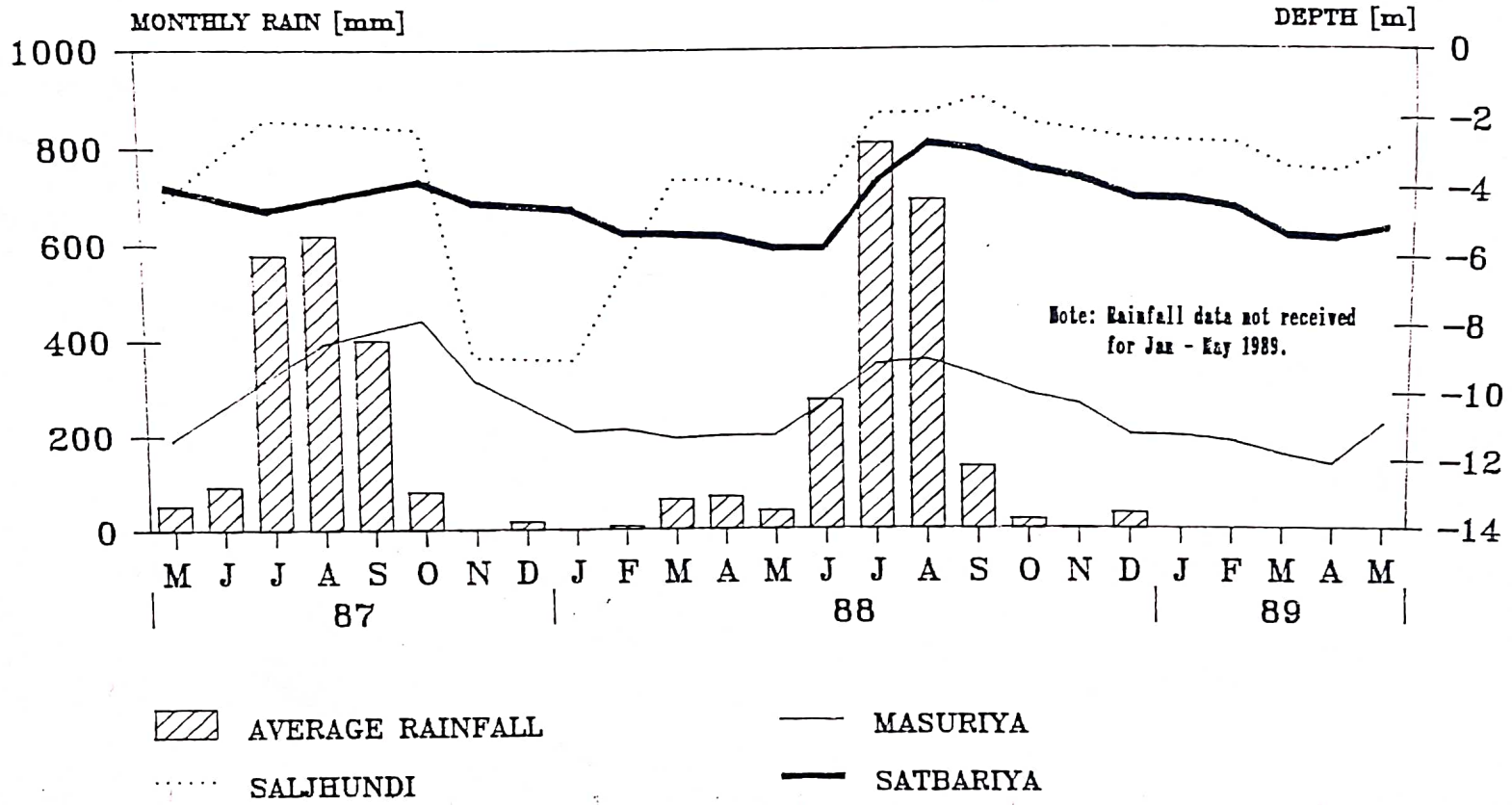
APPENDIX 6

DEPTH TO WATER TABLE & RAINFALL
SHALLOW TUBEWELLS
(1987, '88 & '89)



APPENDIX 7/1

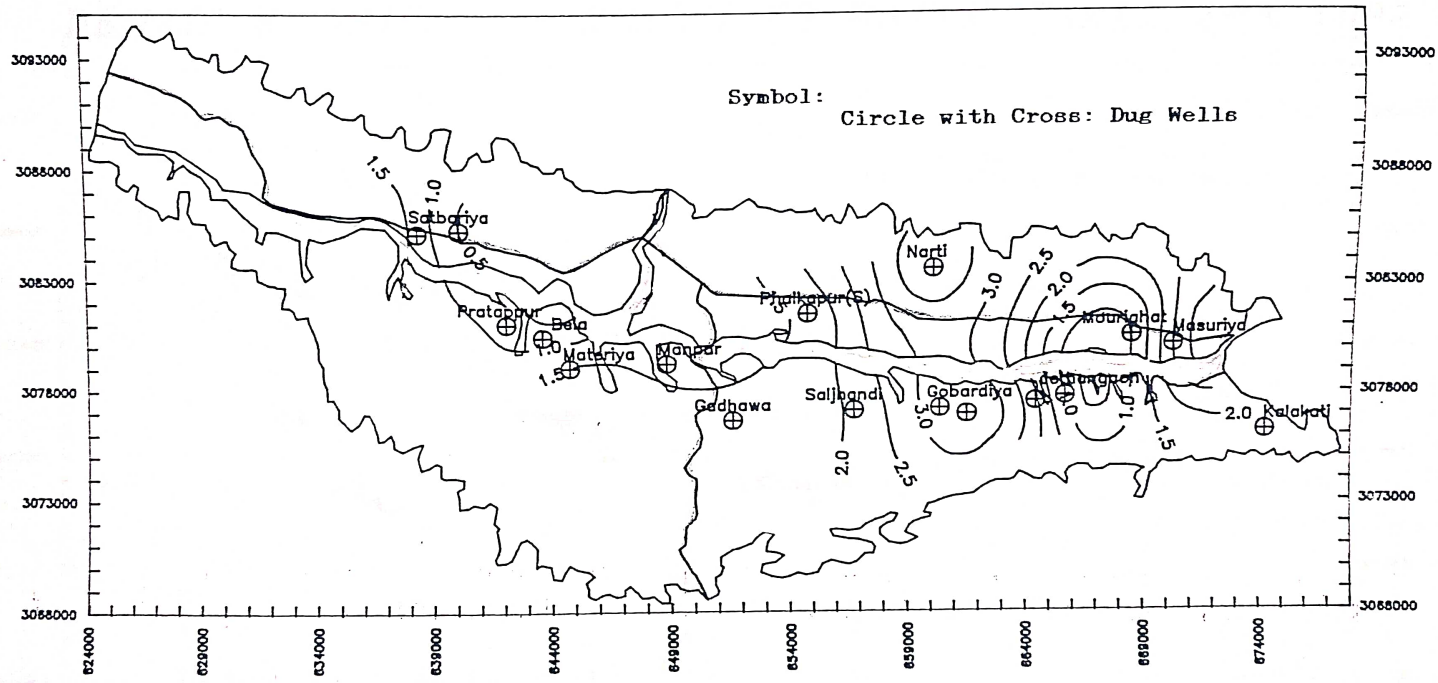
DEPTH TO WATER TABLE & RAINFALL
DUGWELLS
(1987, '88 & '89)



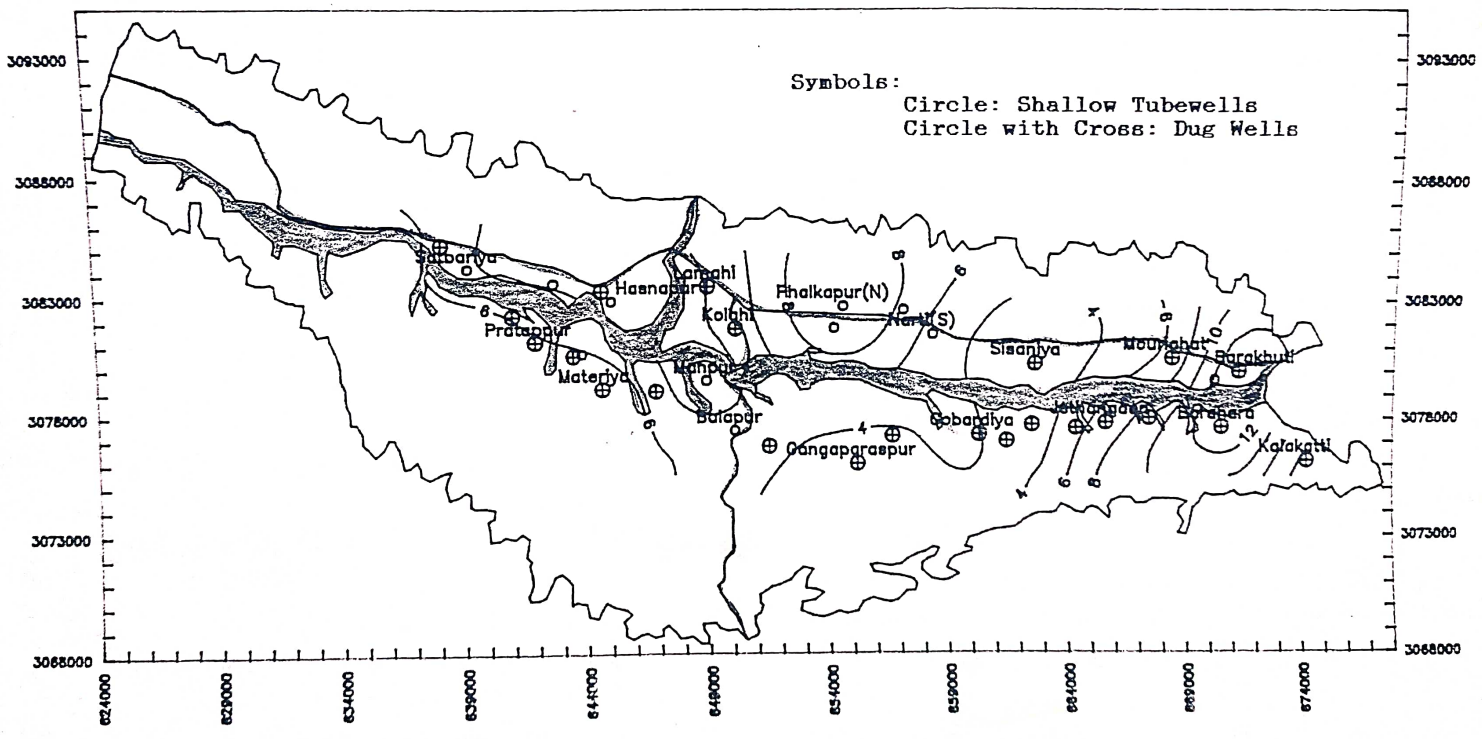
APPENDIX 7/2

APPENDIX 8/1

DEUKHURI VALLEY – RISE OF WATER TABLE MAY – OCT 1987

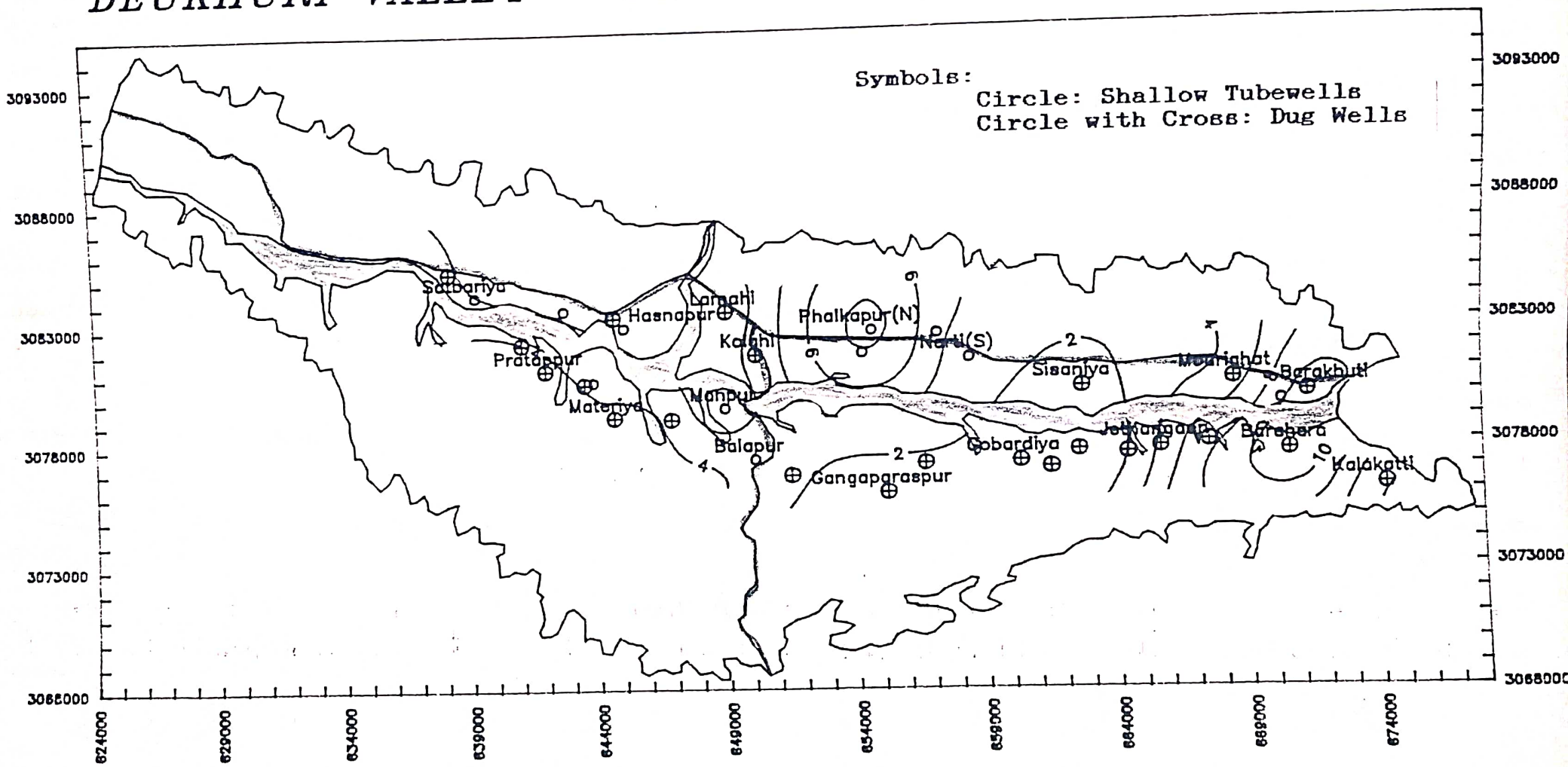


DEUKHURI VALLEY – DEPTH TO WATER TABLE APR 1988



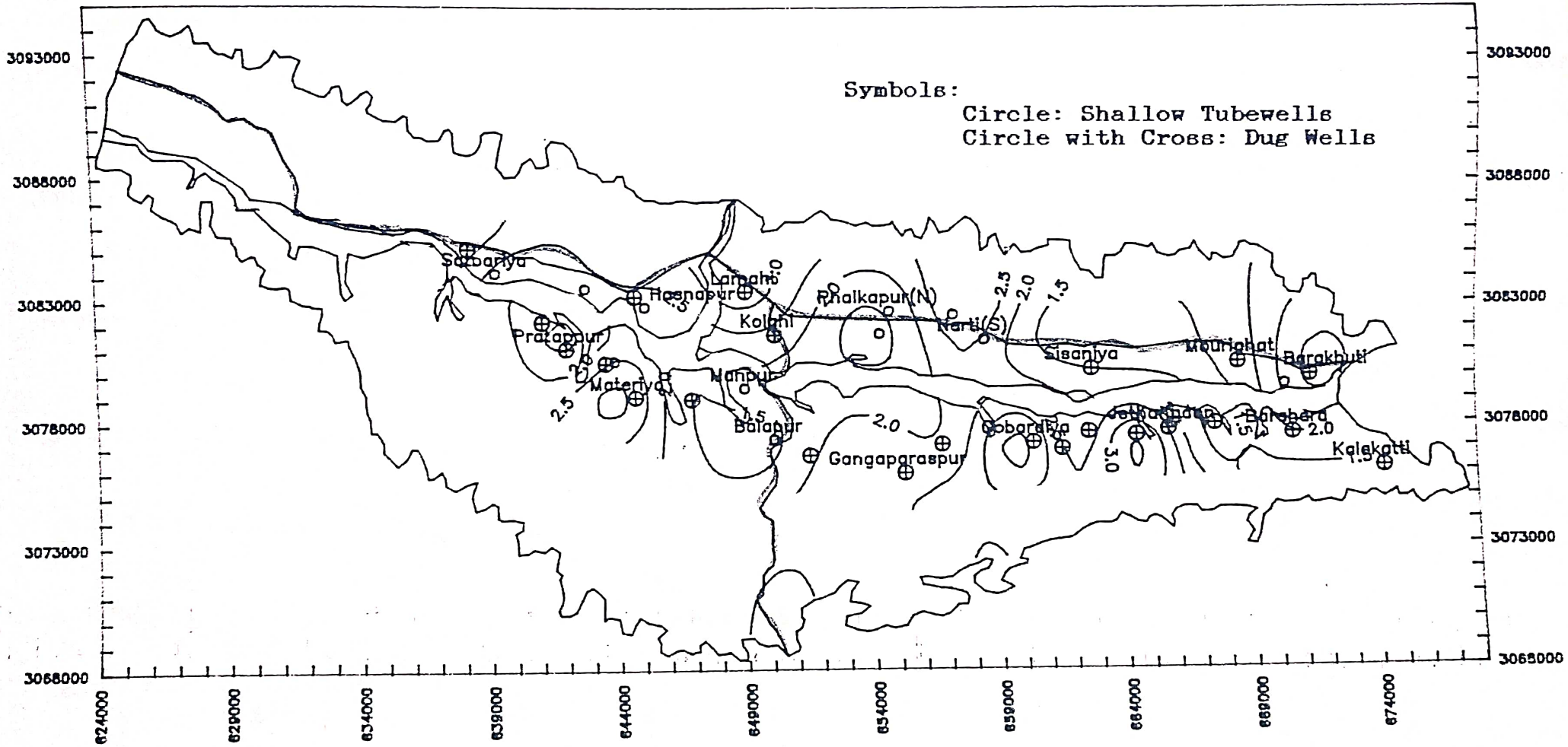
APPENDIX 8/2

DEUKHURI VALLEY – DEPTH TO WATER TABLE AUG 1988



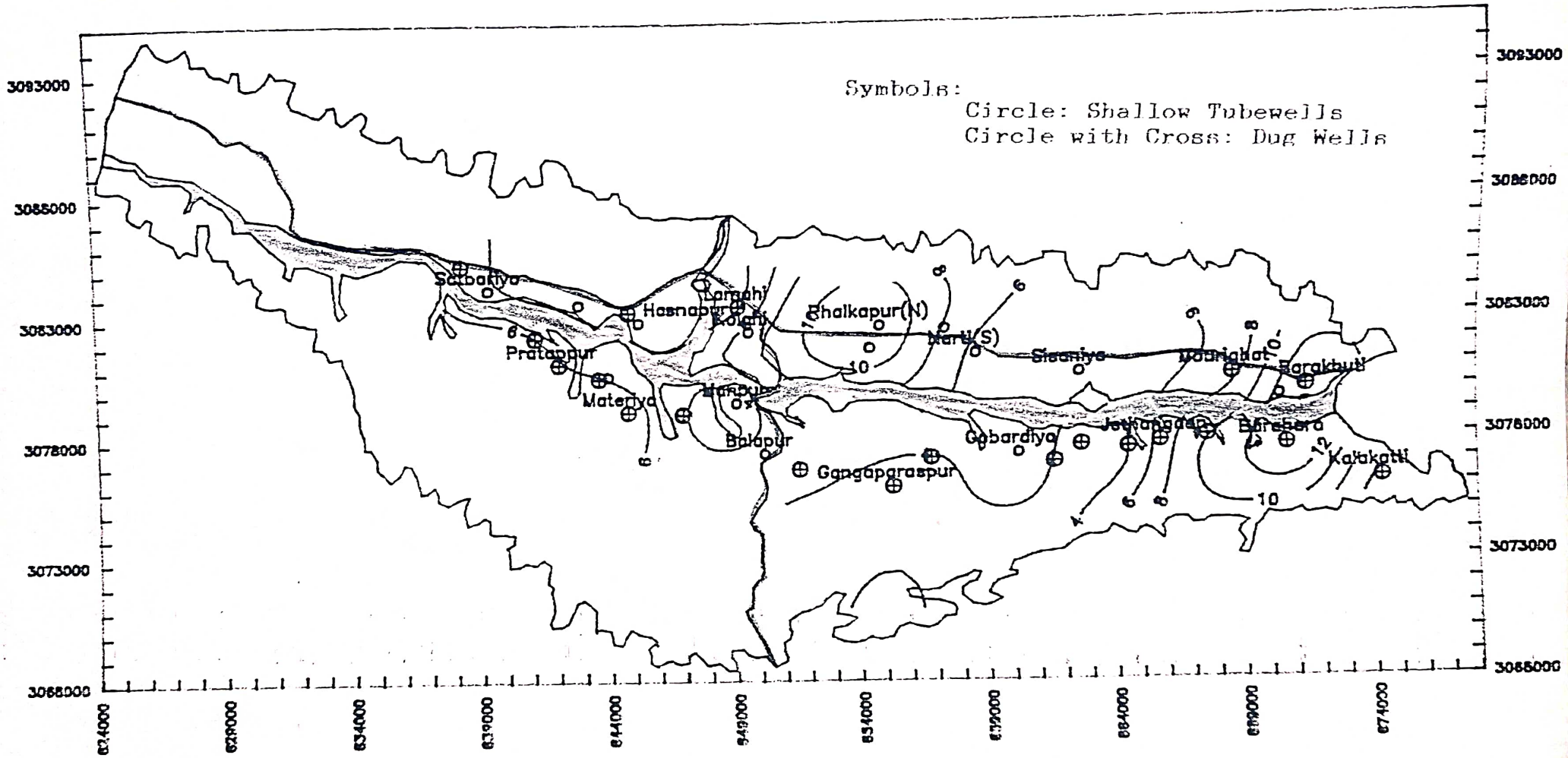
APPENDIX 8/3

DEUKHURI VALLEY – RISE OF WATER TABLE APR – AUG 1988



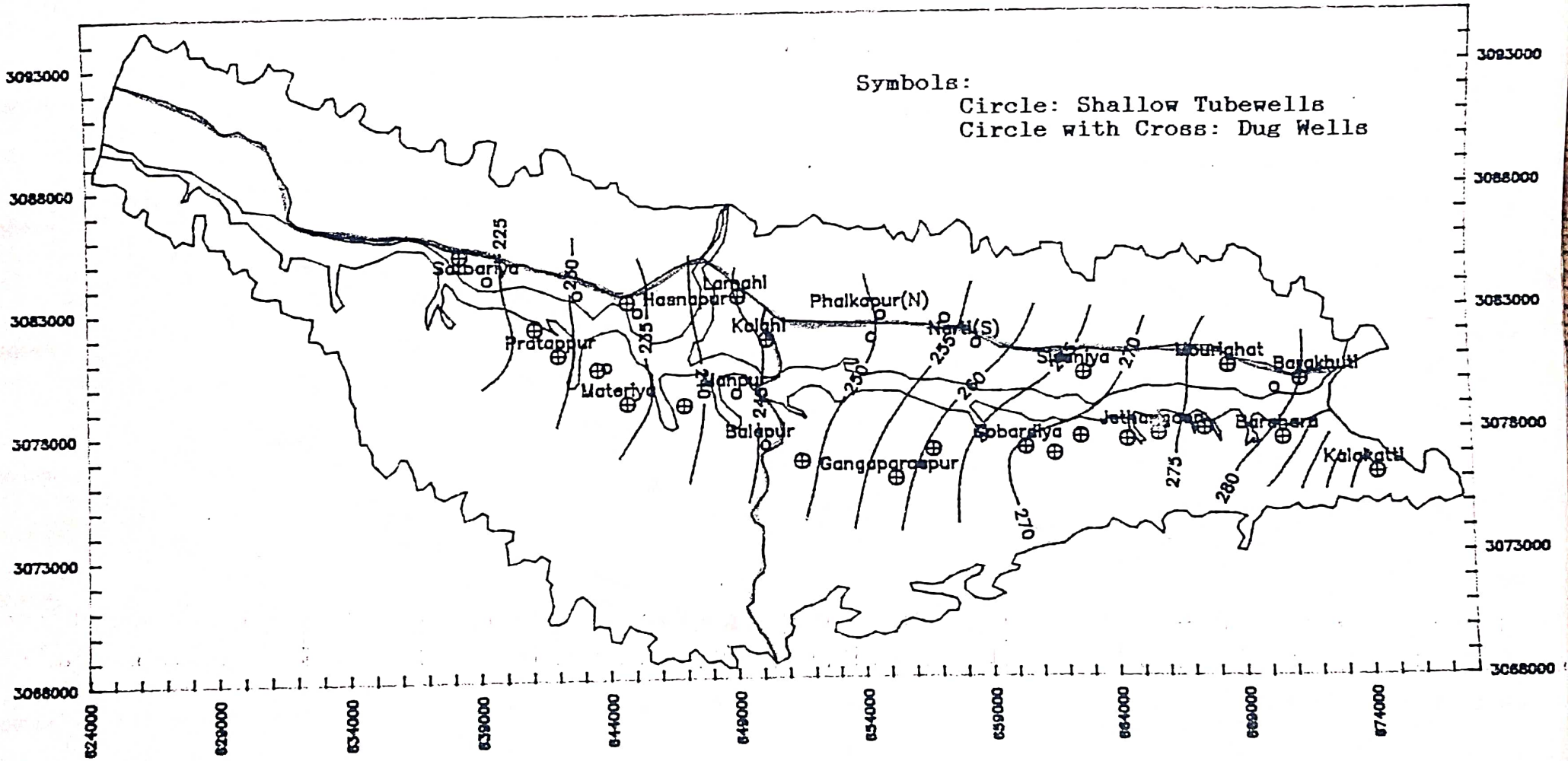
APPENDIX 8/4

DEUKHURI VALLEY – DEPTH TO WATER TABLE APR 1989



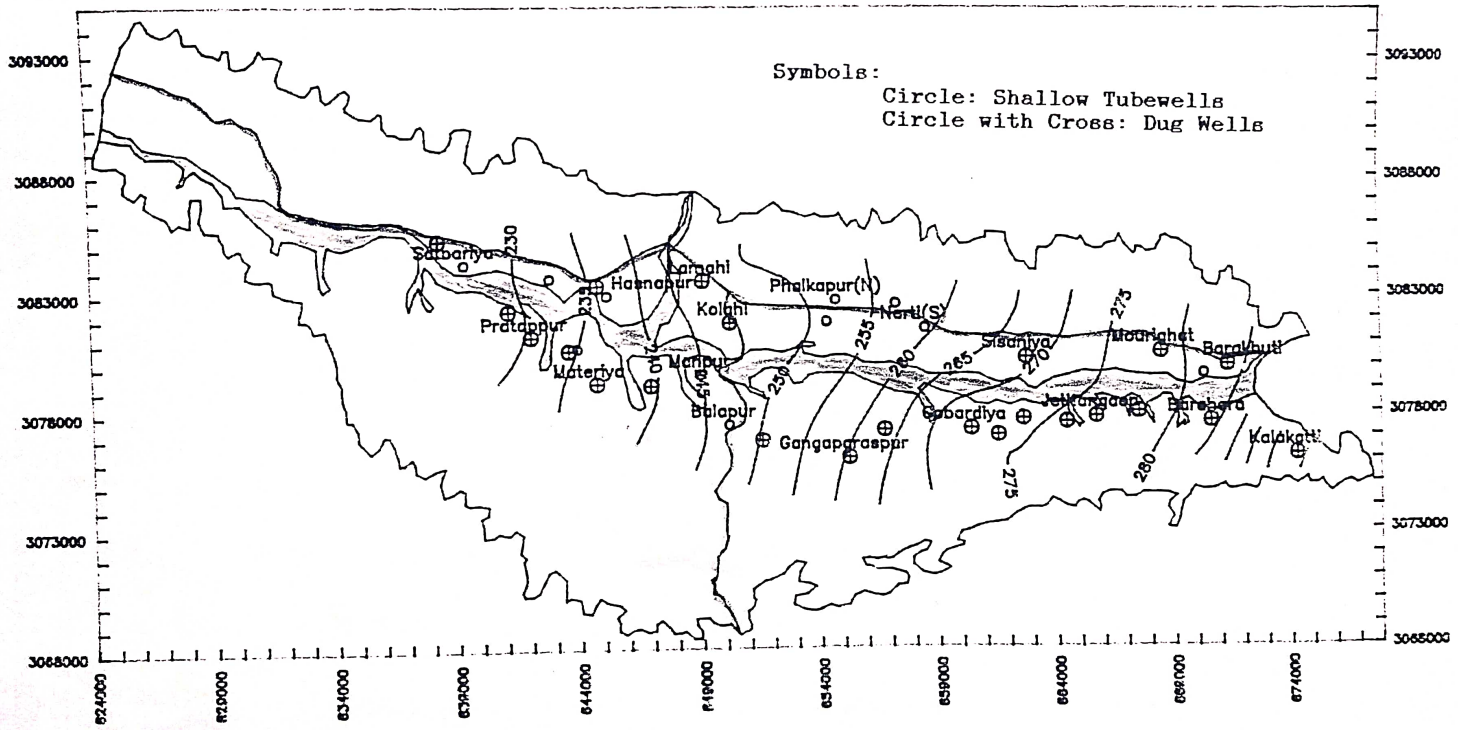
APPENDIX 8/5

DEUKHURI VALLEY – WATER LEVEL CONTOUR MAP APR 1988



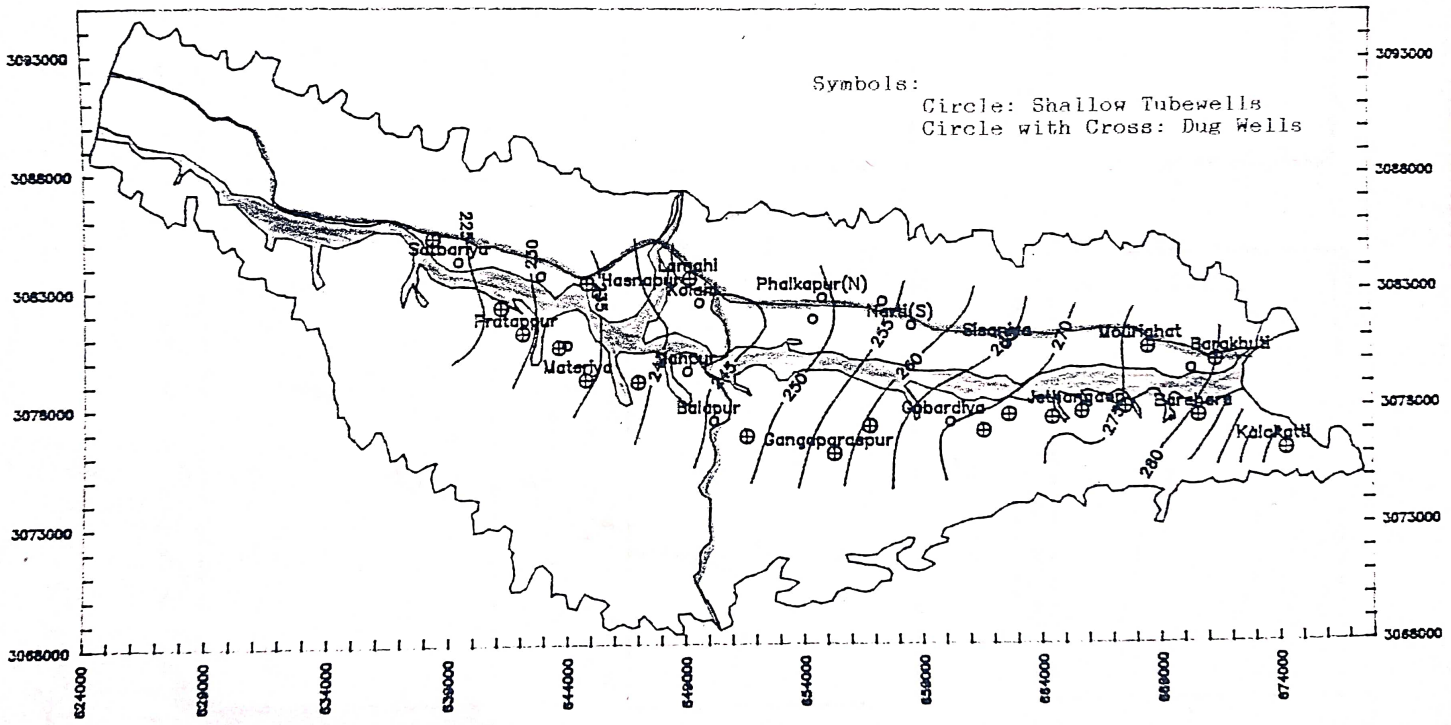
APPENDIX 9/1

DEUKHURI VALLEY – WATER LEVEL CONTOUR MAP AUG 1988



APPENDIX 9/2

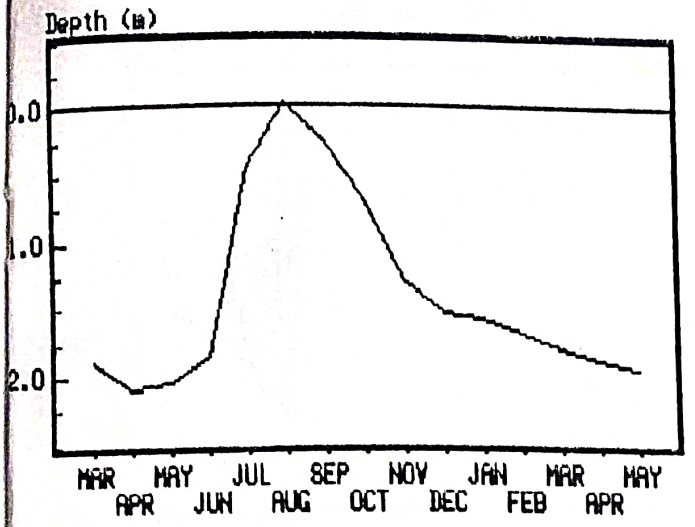
DEUKHURI VALLEY – WATER LEVEL CONTOUR MAP APR 1989



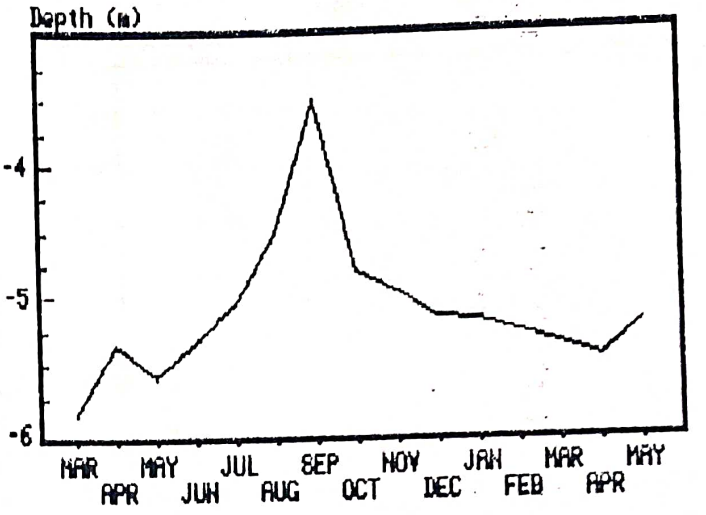
APPENDIX 9/3

HYDROGRAPHS

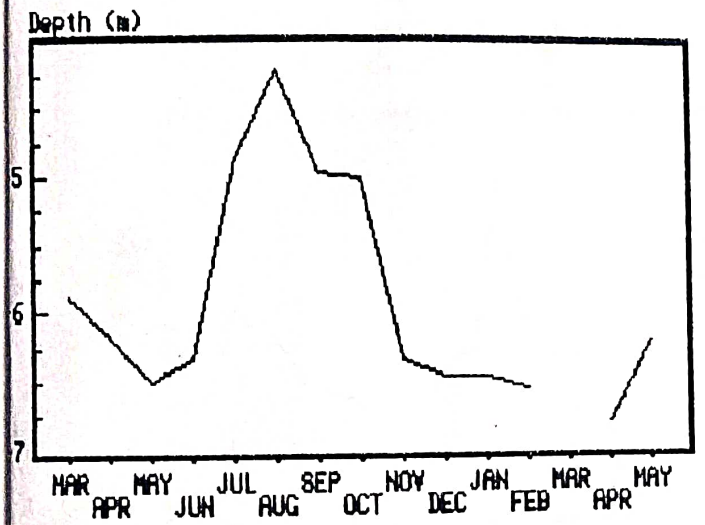
HASNAPUR - UN STW
1988/89



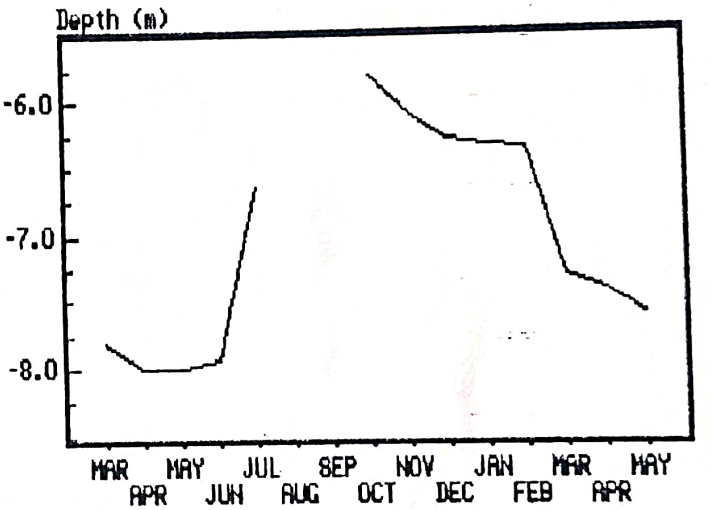
BALAPUR - UN STW
1988/89



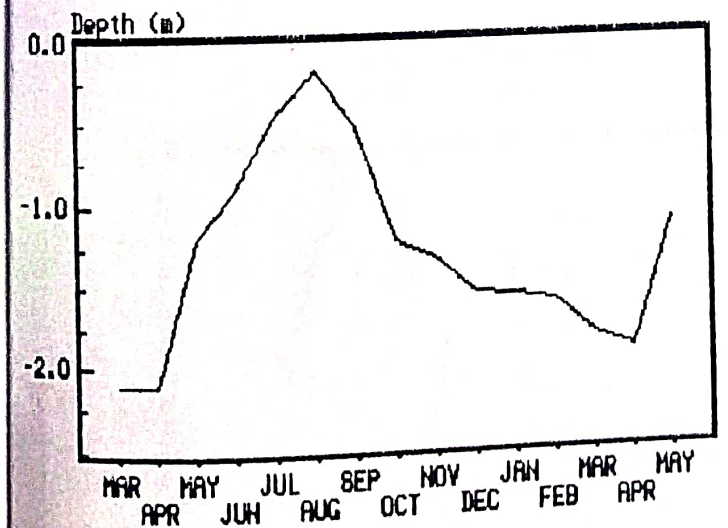
GAHIRA GAON - UN STW
1988/89



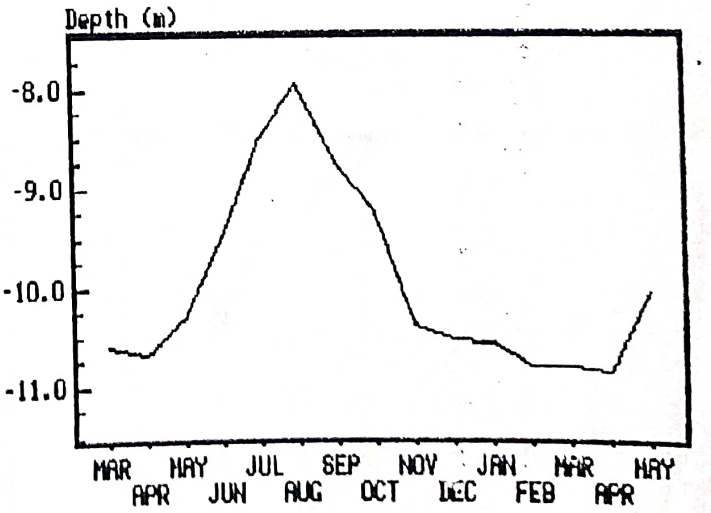
GOBARDIYA - UN STW
1988/89



MANPUR - UN STW
1988/89



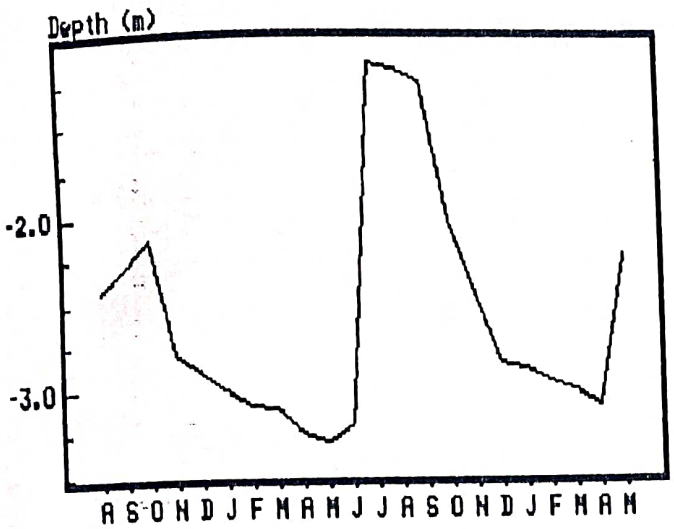
MASURIYA - UN STW
1988/89



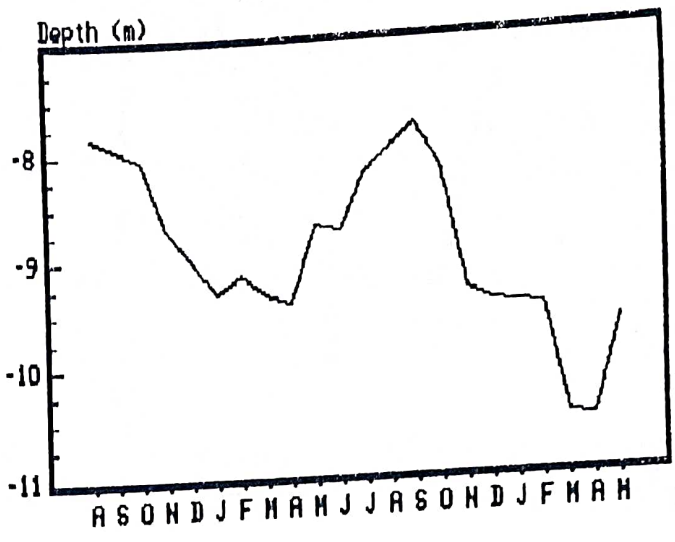
APPENDIX 10/1

HYDROGRAPHS

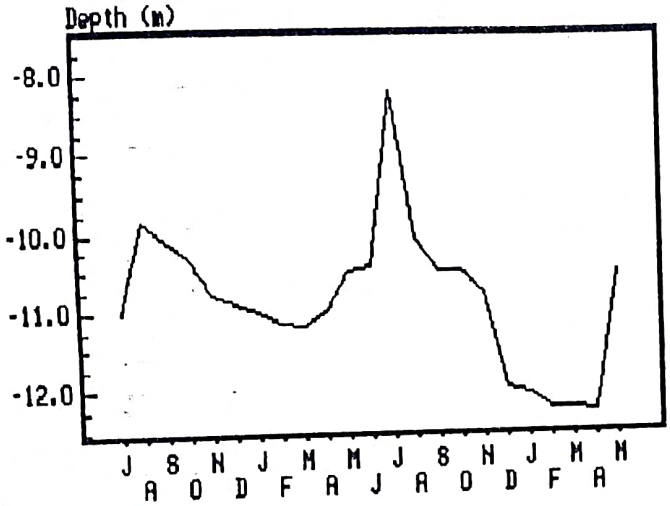
SATBARIYA - GW STW
AUG '87 - MAY '89



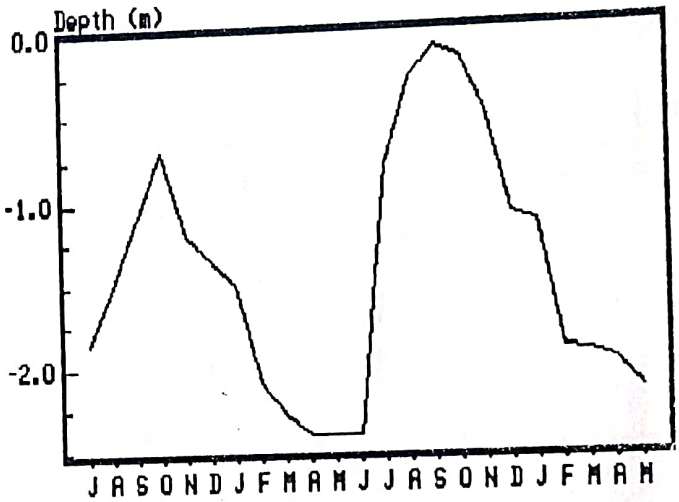
KOLAHI - GW STW
AUG '87 - MAY '89



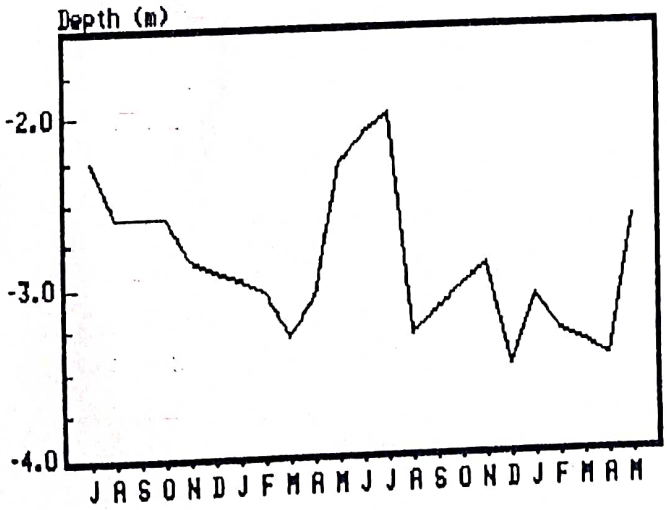
PHALKAPUR NORTH - GW STW
JUL '87 - MAY '89



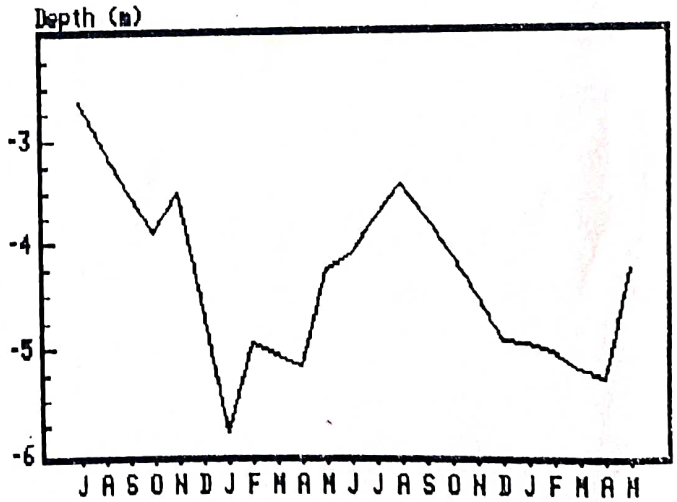
UNCHANIBU - GW STW
JUL '87 - MAY '89



SISANIYA - GW STW
JUL '87 - MAY '89



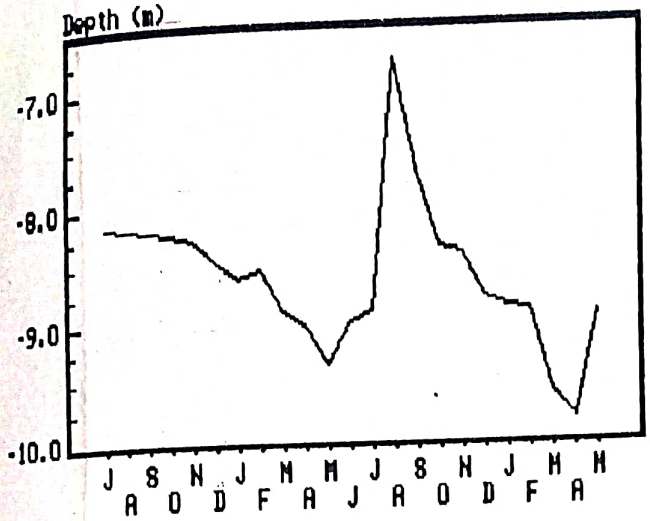
NARTI SOUTH - GW STW
JUL '87 - MAY '89



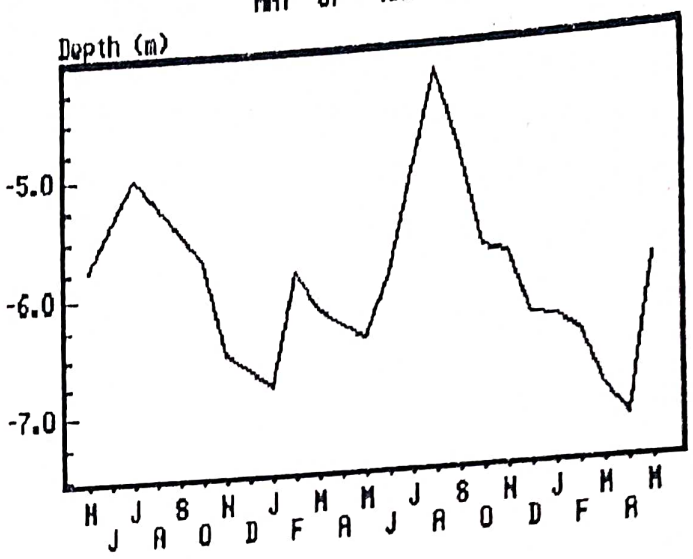
APPENDIX 10/2

HYDROGRAPHS

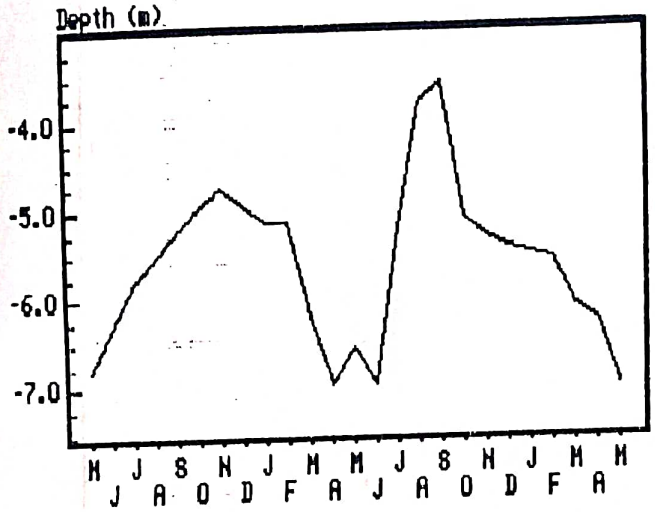
KHARDARIYA - DUG WELL
JUL '87 - MAY '89



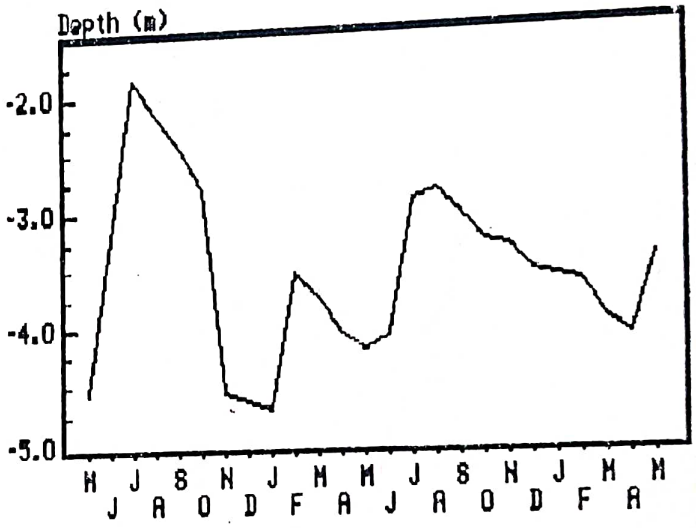
JETHANGRAH - DUG WELL
MAY '87 - MAY '89



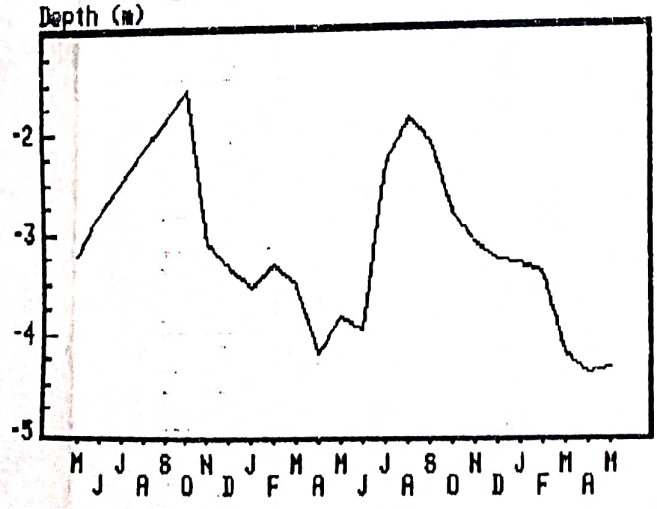
MATERIYA - DUG WELL
MAY '87 - MAY '89



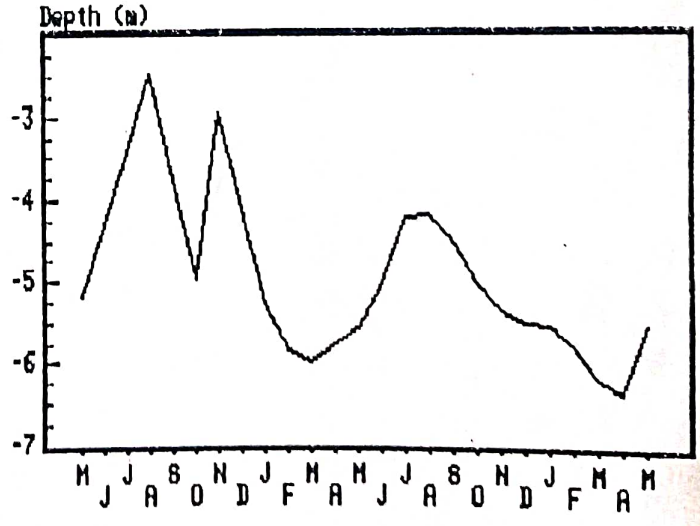
KALAKATTI - DUG WELL
MAY '87 - MAY '89



GADHAWA - DUG WELL
MAY '87 - MAY '89



MOURIGHAT - DUG WELL
MAY '87 - MAY '89



APPENDIX 10/3