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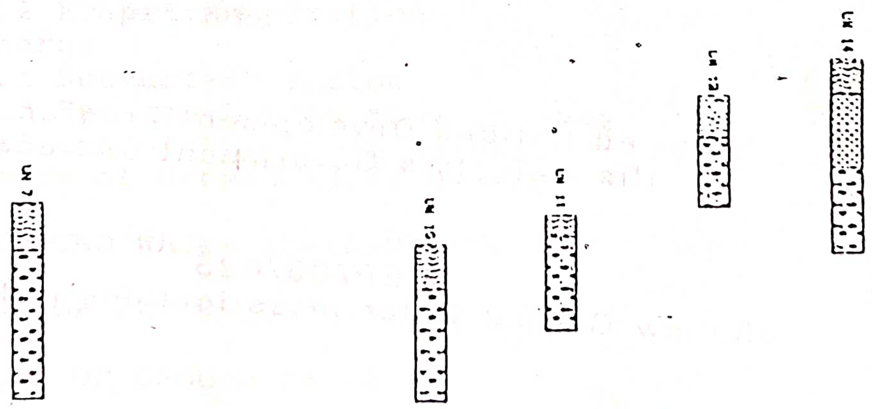
Shallow Ground Water Resources of the Terai Chitwan District Central Development Region, Nepal

Technical Report No. 29

By
DIBYA RATNA KANSAKAR, Divisional Geologist, GWRDB
and
SHANMUKHESH CHANDRA AMATYA, Geohydrologist, GWRDB



United Nations Development Program and
His Majesty's Government of Nepal

NEP/86/025
Shallow Ground Water Investigations in the Terai
March 1993

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

Implementing Agency:
Ground Water Resources Development Board, HMG, Nepal

March 1993

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ABBREVIATIONS

ADB	- Asian Development Bank
ADBN	- Agriculture Development Bank of Nepal
DTW	- Deep Tube Well
GDC	- Groundwater Development Consultants (International) Ltd.
GWRDB	- Ground Water Resources Development Board
GWS	- Ground Water Software, UN/DTCD.
MCM	- Million Cubic Meters
NRSC	- National Remote Sensing Center, Nepal/GTZ/World Bank
STW	- Shallow Tube Well
UNDP	- United Nations Development Program
UN/DTCD	- United Nations Department of Technical Co-operation for Development

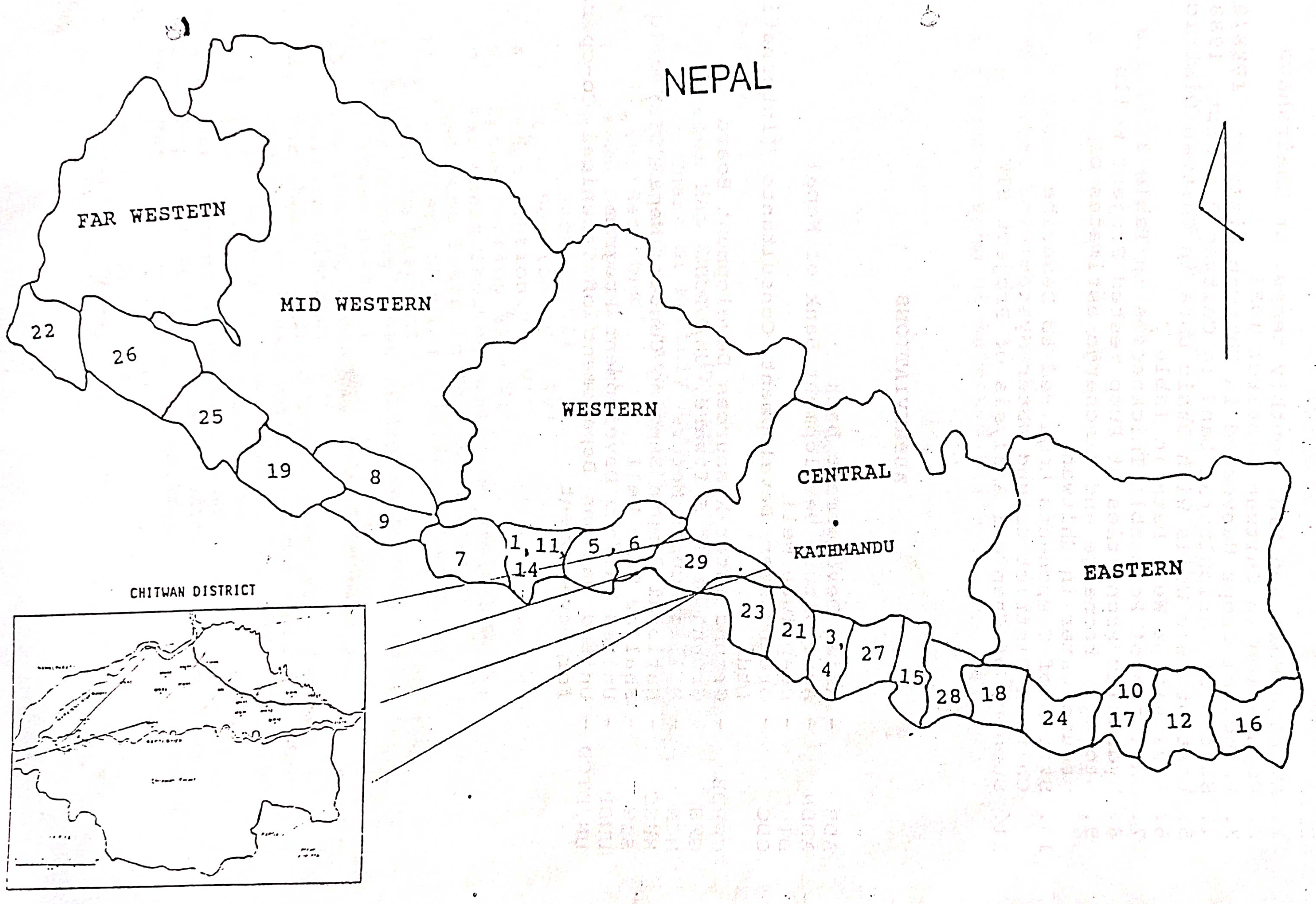


Figure 1. Index Map Showing Technical Reports from the Ground Water Investigations in the Terai

ABSTRACT

Chitwan District, lying in the Central Development Region, has a total surface area of about 2218 km^2. The average annual precipitation in the period between 1990 and 1992 is about 1700 millimeters of which more than 85% is received during the monsoon. The population in Chitwan, according to the 1981 census, was 259,571, out of which almost 90% live in rural setting. Agriculture is the dominant economic activity in the district. Approximately 37.29% of the farm land is irrigated for a single crop and only about 30.33% is irrigated year round. The present investigation has indicated that the aquifer in Chitwan has the potential to provide water to irrigate a substantial proportion of the remaining 69.67% of un-irrigated or single crop irrigated land.

The aquifer is comprised of an indeterminate number of interconnected lenses of sand, gravel and boulders intercalated with some silts and clays which comprise a very large ground water reservoir. Six pumping tests were conducted and transmissivities were determined to range from a low of 767 to as high as 6423 m^2/day. Yields of existing wells range from 5 to 22 liters per second (l/s). The yield potential map indicates that the central part of the area has the highest value.

Fluctuations observed in the water level change are relatively small and are due to seasonal variation and are not due to pumping stress on the aquifer.

Recharge in the Chitwan District aquifer is principally from local precipitation. Estimates of potential recharge vary from 142 MCM to 421.6 MCM per year. This compares favorably with the estimated ground water outflow to Narayani River of 30.4 MCM per year and a hypothetical pumpage of 29.3 MCM per year calculated from 251 wells pumping 15 l/s for six hours each day.

1. INTRODUCTION

1.1 Purpose and Scope

The United Nations Department of Technical Co-operation for Development(UN/DTCD) and the Ground Water Resources Development Board (GWRDB), HMG/Nepal instituted a project in 1987, NEP/86/025, to investigate the shallow ground water resources of "Districts in the Terai". This report on Chitwan District is one of a series of reports from the project. The status of the project is shown in Figure 1.

The purpose of the project is to conduct an orderly and defined investigation of shallow ground water in each Terai district. A major goal of NEP/86/025 project is to develop scientific procedures for the collection, interpretation, and presentation of ground water data, throughout the Terai in Nepal.

A principal component of this goal is the development of a computerized Ground Water Information System (GWIS) to manage the groundwater information obtained in this project. Eventually the GWIS should become a major tool in many aspects of groundwater data storage, retrieval, and dissemination for all groundwater information collected by Department of Irrigation (DOI).

A second major goal is to train Nepalese hydrogeologists to implement the procedures. This should facilitate optimum development of ground water resources of the Terai, in particular, and Nepal in general.

A third major goal is to define the areal extent of each Terai district where a shallow irrigation well (SIW) may be developed. A SIW is defined in the section on shallow ground water availability.

Ground water must be utilized in the best possible manner to ensure availability of this most important natural resource now and in the future. Irrigation wells in Chitwan District and in the Terai will help Nepal increase agricultural production for an increasing population, for export, for valuable foreign exchange, and demonstrates the economic importance of ground water.

This report should be considered in light of the above goals. Ground water data has been collected, placed in an information system and is being interpreted and presented. Training takes place during these activities, and finally, an area is defined where a SIW may be located.

1.2 Location and Extent of Area

Chitwan District lies in the Central Development Region of Nepal. It lies between the LANDSAT IMAGERY (NRSC, 1987) co-ordinates: X = 195000 - 280000 and Y = 3030000 - 3085000. Nawal Parasi District borders on the west along the Narayani River and Makawanpur District on the east. It has India to its south and the Tanahun, Gorkha and Dhading Districts to the north. Bharatpur is the administrative headquarter of this district, and is served by the national East-West Highway and the Mugling-Narayanghat Highway. The total area of Chitwan District is about 2218 km^2 (Statistical Pocket Book,Nepal(SPBN),1990). The Chitwan Dun valley is shown in the inset in figure 1 and is the part discussed in this report.

1.3 Previous Investigations

Chitwan and surrounding districts have been investigated and studied previously by several workers and projects. Reports by these investigators are listed in the selected references.

1.4 Methods of Investigation

Field work in this district began in the month of January 1991 and for the most part was completed in July 1991. The work consisted of drilling wells, making water level measurements, lithologic determinations and aquifer tests. Altitude survey of land surfaces at wells were carried out in 1991 (DEVTEC Nepal,1991).

Water level monitoring in Chitwan District was initiated in November 1988 with an ambitious monitoring network that included 58 dug wells, but for various reasons, regular monthly water level measurements in only 12 of those wells are continued. It is only since August 1990 that a regular water level measurement data from a monitoring network consisting of the Project drilled wells became available.

The current project had drilled 17 STW wells that averaged 10.2 m in depth for a total of 173.4 m. The new wells were located to obtain maximum geographic coverage within the district and thus maximum information about the nature of the aquifer. Manual methods were used to drill 16 of the new wells and only 1 well was drilled with a rotary rig. Drill cuttings were collected and examined. Lithologic logs and other information were collected on 17 project drilled Shallow Tube Wells (STW), and one shallow and one deep tubewell drilled by a private company for the Coca Cola Company.

Aquifer or pumping tests were conducted on 6 of the project wells and two observation wells. However, these tests were marginally performed.

1.5 Well Identification System

Wells in this report are identified in several ways: 1) they are numbered sequentially and given a location name; 2) each has a computer file name or number which includes the letters CH for Chitwan District and the sequence number; 3) additional identification (ID) is provided by another secondary number to differentiate wells drilled for this project (UN and a sequential number) from private wells drilled by Nippon Koi.(NIPP and a sequential number); 4) X and Y coordinates have been digitized from the 1:500,000 LANDSAT imagery map of Nepal and are another ID.

1.6 Topography and Drainage

Physiographically, the Chitwan District lies in the Dun Valley of Nepal within Siwalik Hills Province in the north and the south. Altitudes in Chitwan District range from more than 1876 meters in the north to about 170 meters in the middle to 880 meters at the border with India.

The Narayani river is the biggest river in the district, which forms the western border with Nawal Parasi District. Rapti River is the second major river flowing westward in the middle of the Chitwan District. Several other streams, such as Anjana, Betari, Khairang, Kairar, Lothar etc. are the other streams in the district. All of these streams flow from north to the south, whereas Jarnaili, Bhowarsut and Harda are the northerly flowing streams joining the westerly flowing Rapti River.

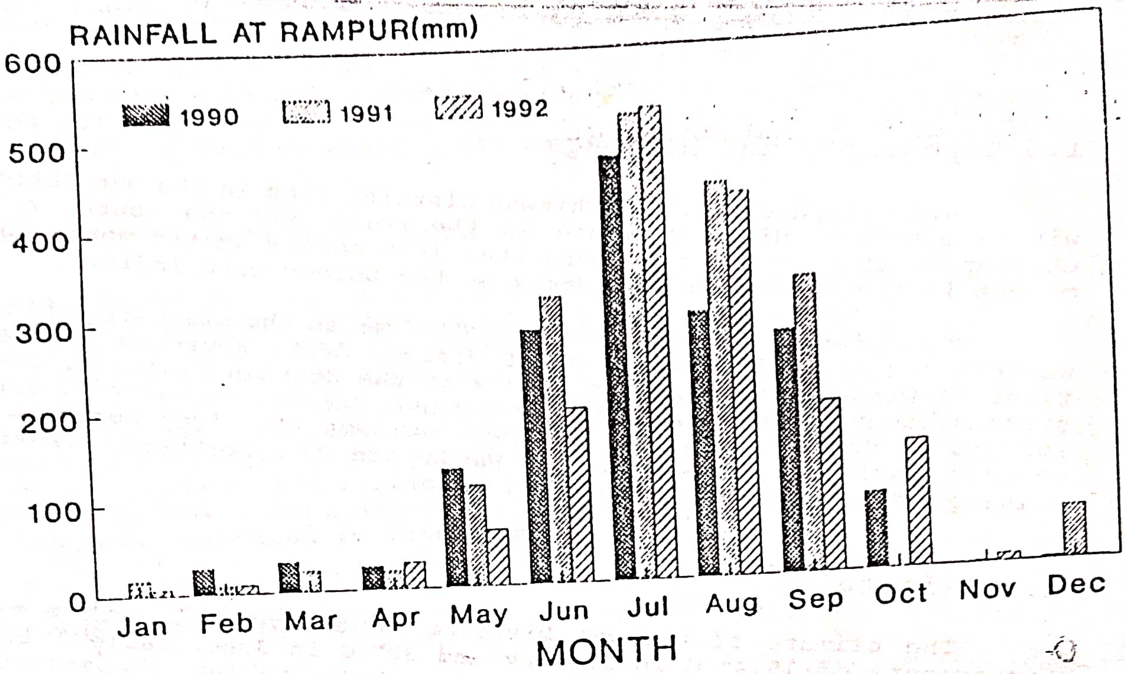
1.7 Climate

The climate of Chitwan District is subtropical with a mean monthly temperature of 15.4° C in January and 30° C in June. Table 1 lists average annual maximum and minimum temperatures at Bhairahawa, (Rupandehi District), the nearest meteorological station to Chitwan District.

Table 1. Average maximum and minimum monthly temperatures at Bhairahawa.

January		February		March		April		May		June	
max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.
27.2	3.5	30.8	3.5	40.2	8.8	43.0	12.2	42.5	17.4	42.2	18.1
July		**August**		**September**		**October**		**November**		**December**	
max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.
39.1	22.6	37.3	19.0	37.0	20.6	35.8	15.4	32.0	9.5	29.1	6.4

High humidity is prevalent except in winter and becomes oppressive in summer. The climatic characteristics of Chitwan District, as in other parts of Terai is that about 85% of the total annual rainfall is delivered by monsoon in four months from June to September. Monthly precipitation is shown in Figure 2. The mean annual rainfall during the three years from 1990 to 1992 recorded at Rampur, Chitwan is 1700 mm.



Total Rainfall in
1990=1643mm, 1991=1859mm, 1992=1596mm
Average Annual Rainfall = 1700 mm

Figure 2. Bar Chart of Monthly Rainfall recorded at Rampur, 1990-1992

1.8 Population

There were about 259,571 people in Chitwan District in 1981 giving an average population density of about 117 persons per km^2 (SPBN,1990). Table 2 lists the figures from the 1981 census. About only 10.6% of the population in Chitwan District were living in an urban setting in 1981.

Table 2. Population in Chitwan district and in Bharatpur in 1981.

	Total Population	Population	
		Male	Female
Chitwan	259,571	133,349	126,222
Bharatpur	27,602	14,407	13,195

Source: Statistical Pocket Book, Nepal, 1990.

1.9 Agriculture

The principal crops grown in Chitwan District are paddy, maize, millet, wheat, barley, oilseeds, potato, tobacco, sugarcane, pulses and other. Statistics for crops are listed in Table 4 (Agricultural Statistics of Nepal (ASN),1990).

Table 3. Principle crops harvested in 1988-1989 in Chitwan district.

Crop	Area (Ha)	Yield (kg/Ha)	Production (Metric Tons)
Paddy	27,830	2,700	75,140
Maize	22,400	1,794	40,190
Millet	810	1,099	890
Wheat	8,070	1600	12,910
Barley	550	873	480
Oilseed	20,010	540	10,810
Potato	750	11,587	8,690
Sugarcane	20	25,[illegible]00	500

Table 10 indicates only 30.33% of potential irrigation land in Chitwan is irrigated the year around, leaving 69.67% or about 16,163 hectares that could be irrigated the whole year. The food requirements of the expanding population of Nepal will require more and more year round irrigation in the Terai and therefore in Chitwan.

Table 4. Status of irrigated land in Chitwan District (1988/89)

Total area	Year round irrigated area	Monsoon irrigated area	Total irrigated area	Total irrigable area	Unirrigated area
	12,726	15,648	28,374	41,963	16,163
100%	30.33%	37.29%	67.62%	100%	69.67%

1.10 Acknowledgements

The information compiled and presented in this report are mostly from the Ground Water Resources Development Board office in Birgunj. The pumping tests carried out on the project drilled shallow tubewells by GWRDB, Birgunj has provided a wealth of valuable information necessary for aquifer evaluation.

The work of the staff engaged in hydrogeological work in Chitwan, both in the field and office, is highly appreciated. The present final report is based on the field data collected by the GWRDB, Birgunj office and are duly acknowledged. The author wishes to express his sincere gratitude to Mr. Y.L. Vaidya, Director General, Department of Irrigation, HMG/Nepal for his support and encouragement to prepare this report. The support and guidelines provided by Dr. R.M. Tuladhar, National coordinator of the Project NEP/86/025, and the staff at the central office, Kathmandu during preparation of this report is much appreciated. Mr. J.M. McNellis, Chief Technical Adviser to the project NEP/86/025 is duly acknowledged for his constant guidance and advice during the preparation of this report.

2. GEOLOGY, LITHOLOGY AND WATER SUPPLY

Sediments comprising the Dun Valleys in the Himalaya are thick clastic deposits of Pleistocene and Quaternary age and are accumulating to the present day. The most permeable portions of the Dun valley sediments are the coarse fractions. Thus sand, gravel and larger fractions will be called aquifer in the succeeding discussion.

2.1 Lithological Cross sections:

The well locations and traces of lithological cross sections for Chitwan District are presented in Figure 3. The individual cross sections produced by using GWS are shown in Figure 4 to 9 and are followed by descriptions. The vertical axis of the individual cross sections represents elevation above mean sea level in meters.

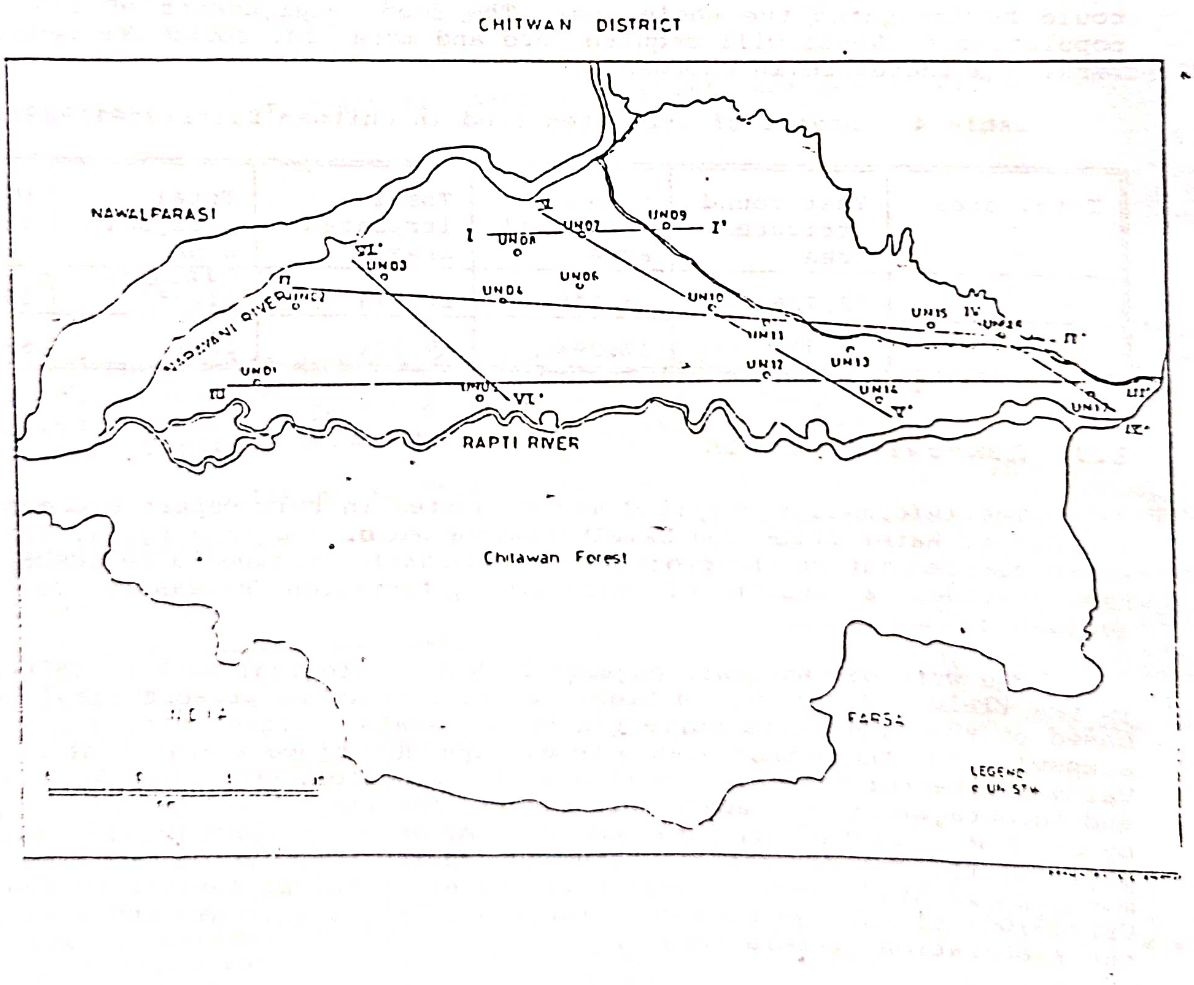


Figure 3. Location of wells and traces of Cross Section lines.

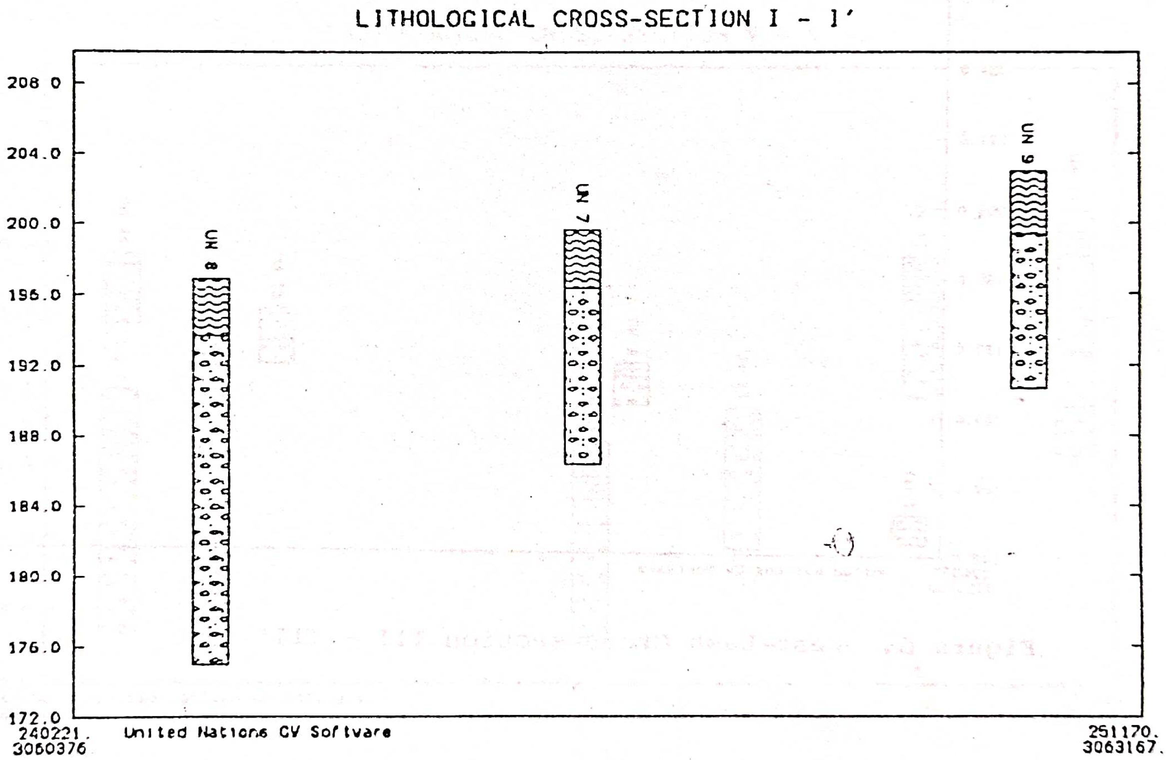


Figure 4. West-East Cross-section I - I'

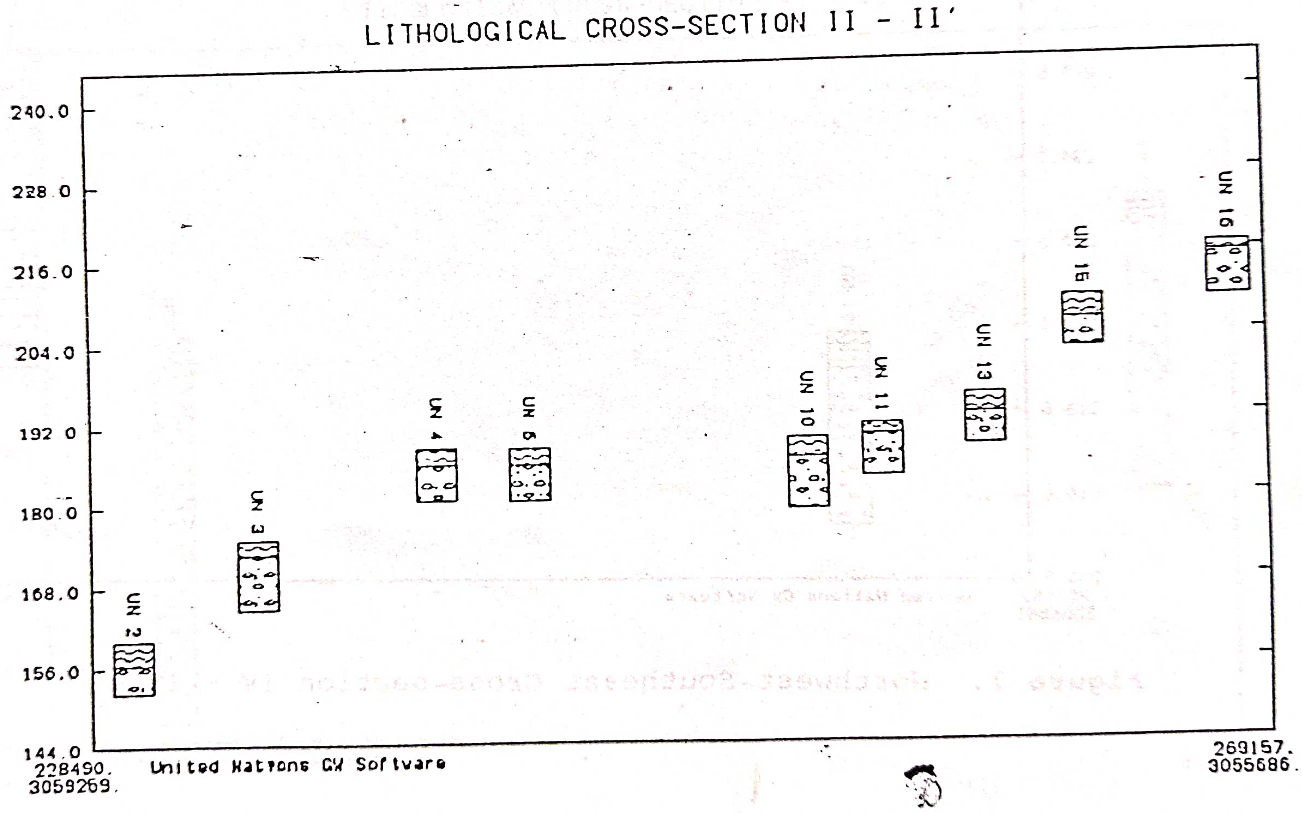


Figure 5. West–East Cross-section II - II'

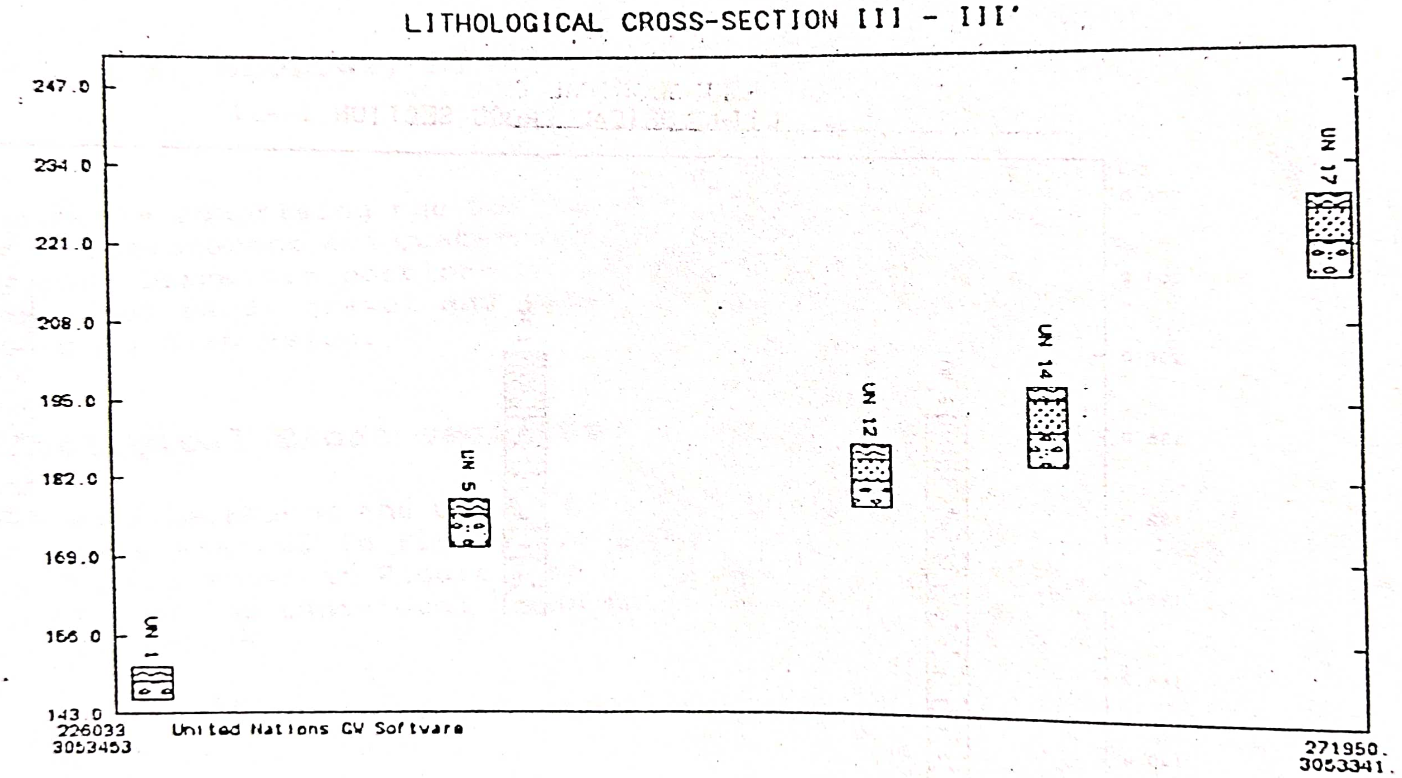


Figure 6. West-East Cross-section III - III'

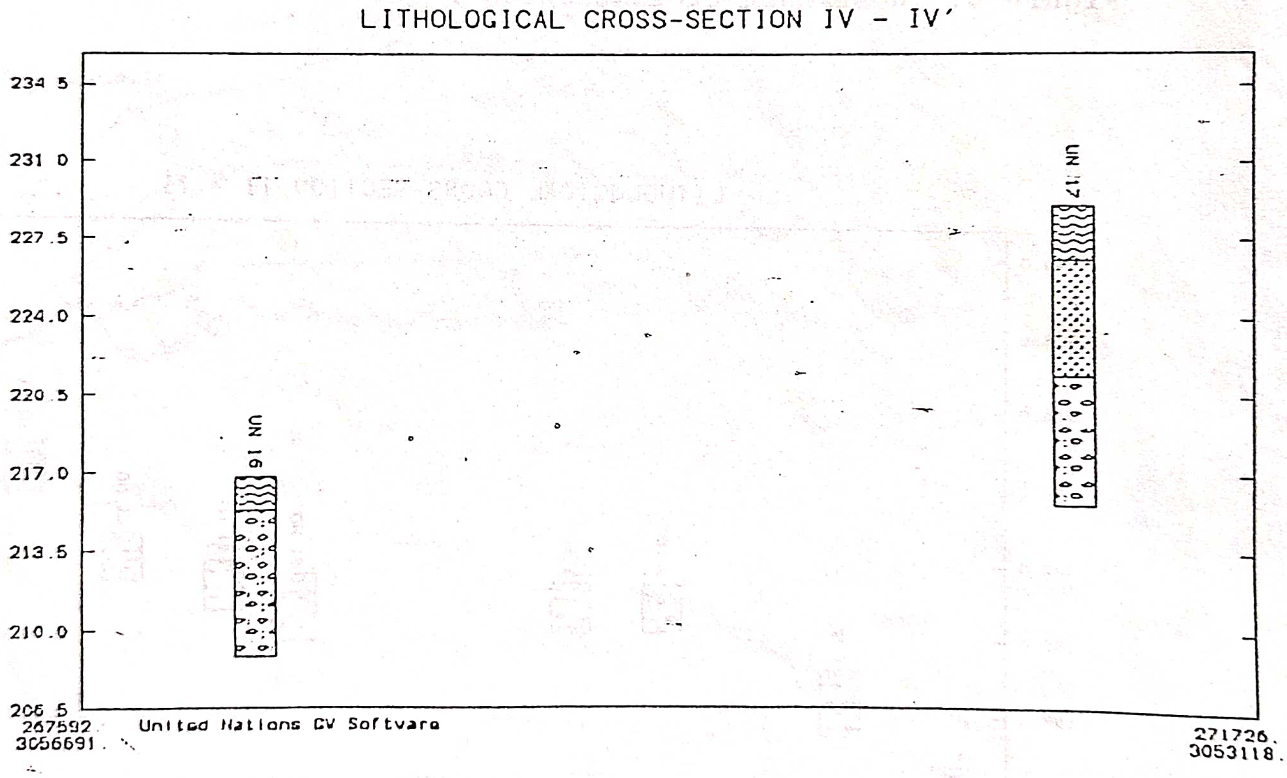


Figure 7. Northwest-Southeast Cross-section IV - IV'

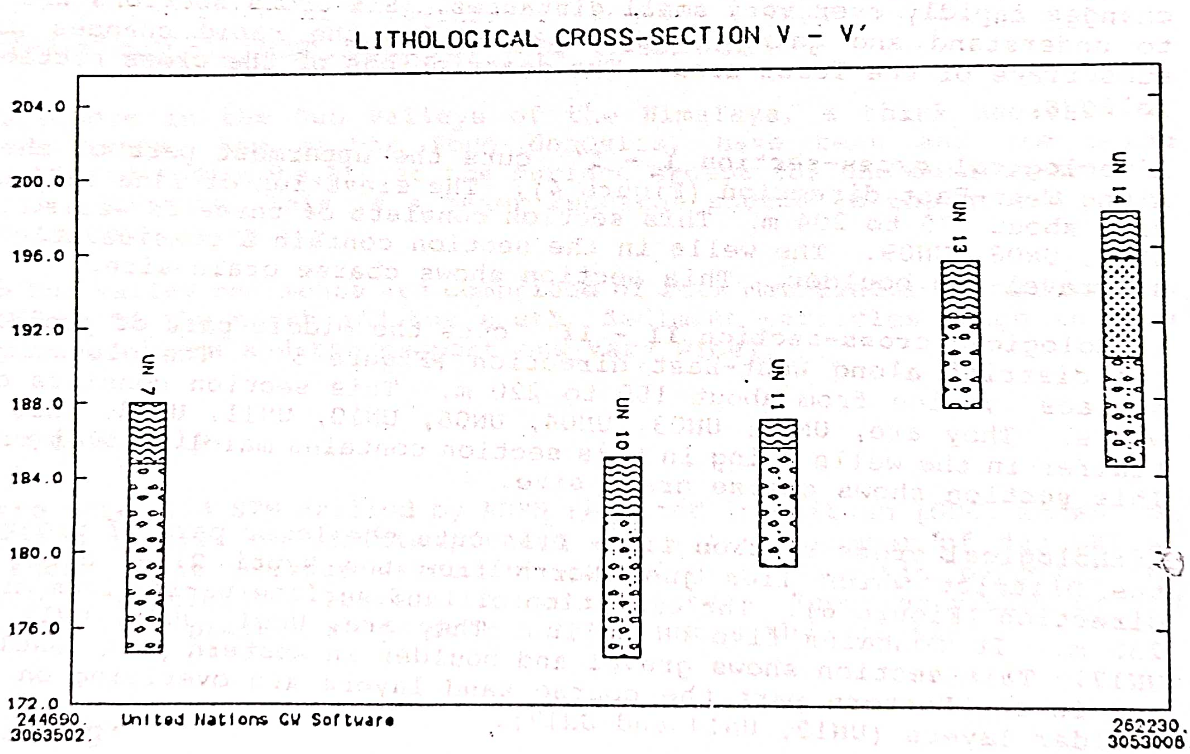


Figure 8. Northwest-Southeast Cross-section V - V'

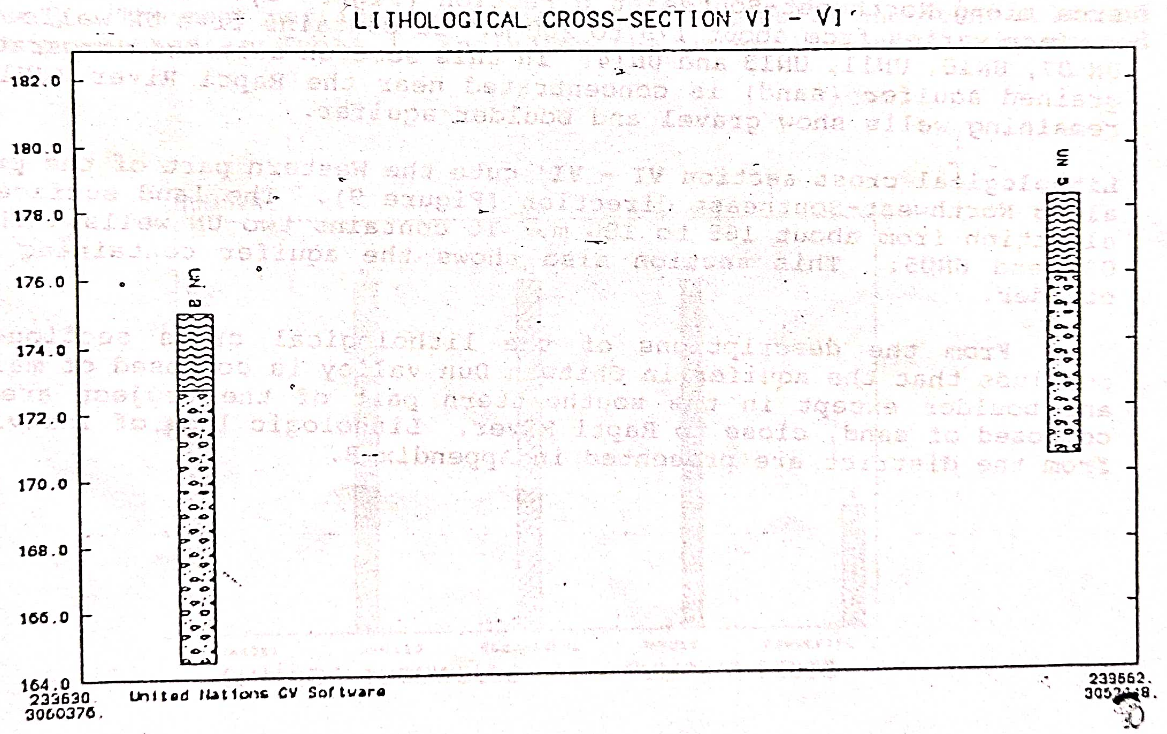


Figure 9. Northwest-Southeast Cross-section VI - VI'

No attempt has been made to connect permeable layers in the cross sections. This is a "risky" undertaking in Quaternary deposits near the Siwaliks and across the Terai Plain which is cross-cut by many present rivers and buried channels of rivers of the past. The lithology of the sediments changes rapidly over very small distances. Six cross sections are presented to understand and gain an appreciation for the rapid changes within the subsurface of the Terai area. The descriptions of the cross sections are as follows.

Lithological cross-section I - I' cuts the uppermost part of the district along West-East direction (Figure 4). The elevation of land surface varies from about 175 to 204 m. This section consists of three UN wells. They are, UN07, UN08, UN09. The wells in the section contain a considerable thickness of gravel and boulder. This section shows coarse grain size.

Lithological cross-section II - II' cuts the middle part of project area of the district along West-East direction (Figure 5). The elevation of land surface varies from about 150 to 220 m. This section consists of nine UN wells. They are, UN02, UN03, UN04, UN06, UN10, UN11, UN13, UN15 and UN16. Aquifer in the wells lying in this section contains mainly gravel and boulder. This section shows coarse grain size.

Lithological cross section III - III' cuts the lower part of project area of the District which lies just North from the Rapti River along West-East direction (Figure 6). The elevation of land surface varies from about 145 to 230 m. It contains five UN wells. They are, UN01, UN05, UN12, UN14, and UN17. This section shows gravel and boulder in western part (UN01 and UN05) and in the Eastern part the coarse sand layers are overlying on gravel and boulder layers (UN12, UN14 and UN17).

Lithological cross section IV - IV' cuts the easternmost part of the project area along Northwest-Southeast direction (Figure 7). The land surface varies in elevation from about 200 to 230 m. It contains two UN wells. They are, UN10, and UN17. This section shows comparatively fine grained aquifer (sand) concentrated near the Rapti River.

Lithological cross section V - V' cuts the almost middle part of the project area along Northwest-Southeast direction (Figure 8). The elevation of land surface varies from about 175 to 200 m. It contains five UN wells. They are, UN 07, UN10, UN11, UN13 and UN14. In this section also the comparatively fine grained aquifer (sand) is concentrated near the Rapti River (UN14) and the remaining wells show gravel and boulder aquifer.

Lithological cross section VI - VI' cuts the Western part of the project area along Northwest-Southeast direction (Figure 9). The land surface varies in elevation from about 165 to 180 m. It contains two UN wells. They are, UN 03, and UN05. This section also shows the aquifer containing gravel and boulder.

From the descriptions of the lithological cross sections, one can conclude that the aquifer in Chitwan Dun valley is composed of mainly gravel and boulder except in the southeastern part of the project area which is composed of sand, close to Rapti River. Lithologic logs of individual wells from the district are presented in Appendix B.

2.2 Dun Valley Deposits

2.2.1 Lithology, Distribution, and Thickness

Everywhere in the Dun Valleys of the Himalaya, a thick sequence of clastic sediments, the Bhabar Zone deposits, have been and are being deposited. These sediments are at the surface except for the outcrop area of the Siwalik sediments. This is a major recharge source to the ground water reservoir in Chitwan valley.

The Dun valley sediments are comprised of rock material eroding from the Siwalik Hills to the north and the south. Sediment particles range in size from clay to boulders and the proportions vary widely.

2.2.2 Water Supply

There were 224 STW drilled by ADBN reported in Chitwan (GDC, inception report, March 1993). In addition, there are a large number of dug wells. Some of these wells provide water for drinking or domestic purposes and others, STW in particular, provide irrigation water. Reported yields of STW drilled under this project range from 5 l/s to more than 22 l/s.

2.3 Drilling:

Lithological logs and other information were collected on 18 drilled wells. One DTW was drilled by Nisaku Japan in Bharatpur for Bottlers Nepal Pvt.Ltd. (private use). This project drilled 17 investigation wells using mannual (Thokuwa) methods for 16 STWs and rig for one STW (UN08). The maximum and minimum drilled depths of the project wells are 22.00 m and 5.25 m respectively and the average drilling depth is 10.2 m. The number of project wells and drilling meterage in Chitwan are shown on Figures 10 and 11 respectively. The most pertinent data on the project wells and other selected wells are presented in Table 3, including the water levels of pump tested wells.

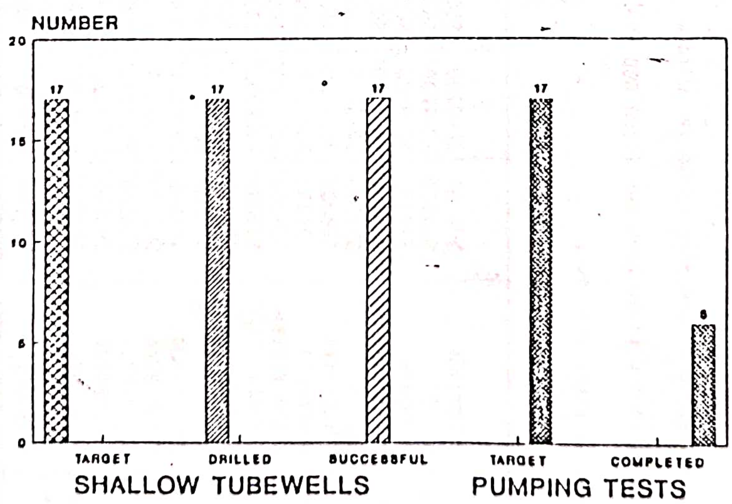


Figure 10: Bar chart of number of wells and pump tests in Chitwan District

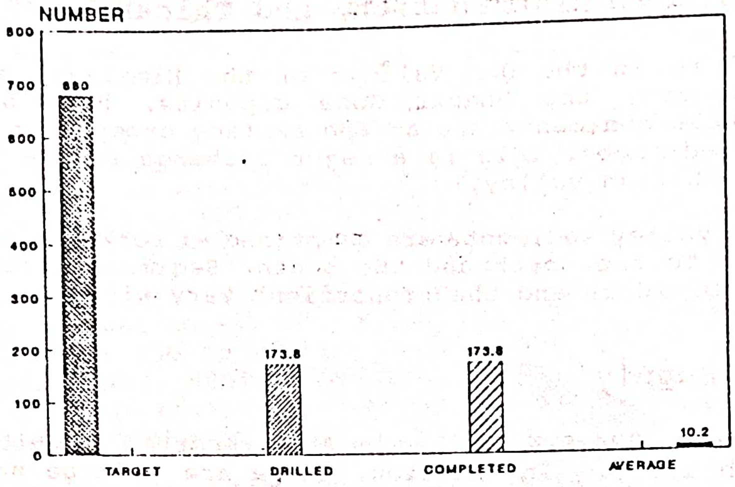


Figure 11: Bar chart of drilling meterage in Chitwan District

TABLE 5. *List of Tube Wells with Basic Data*

S. No.	File Name in Computer	Well Number (1)	Location			Elev. from MSL (m) (3)	Depth of Well (m)	Length of Screen used (m)	Screen Position (m)	Screen Type	Permeable Thickness (m)	Permeable Percent of depth (m)	Drilling Date	Well Diameter (inch)	Water Level BGL (m)
			Village Name	Landsat Co-ordinates (2)											
				X	Y										
1	CHS01.LTH	UN 01	MEGHAULI	227250.	3054000.	150.66	5.25	2.7	2.50- 5.25	Perforated	3.0	57.1	10.07.91	4	
2	CHS02.LTH	UN 02*	DIBYA NAGAR	229500.	3058250.	159.95	7.75	2.7	5.50- 7.75	,,	4.1	52.9	08.07.91	4	2.80
3	CHS03.LTH	UN 03*	BHIMNAGAR	234250.	3059500.	175.00	10.50	2.7	7.75-10.50	,,	8.2	78.6	05.07.91	4	0.56
4	CHS04.LTH	UN 04	SHIVANAGAR	240500.	3058250.	188.20	7.85	2.7	5.10- 7.85	,,	5.4	69.0	17.01.91	4	2.80
5	CHS05.LTH	UN 05	PATHIHANI	239250.	3053000.	178.39	7.85	2.7	5.10- 7.85	,,	5.4	69.0	21.01.91	4	2.62
6	CHS06.LTH	UN 06	GEETANAGAR	243750.	3057750.	187.93	7.85	2.7	5.10- 5.85	,,	5.4	69.0	19.01.91	4	2.79
7	CHS07.LTH	UN 07	NARAYANPUR	245250.	3062250.	188.00	13.25	2.7	10.50-13.25	,,	10.0	75.5	12.01.91	4	
8	CHS08.LTH	UN 08	PREMBASTI	241500.	3061000.	184.00	22.00	5.5	16.10-24.60	Slotted	18.7	85.2	09.03.91	6	9.75
9	CHS09.LTH	UN 09	GODRANG	250000.	3063000.	193.00	12.42	2.7	9.67-12.42	Perforated	8.8	70.6	05.01.91	4	2.65
10	CHS10.LTH	UN 10*	TIKAULI	253500.	3058000.	185.00	10.50	2.7	7.75-10.50	,,	7.5	71.0	02.01.91	4	2.60
11	CHS11.LTH	UN 11	RATAN NAGAR	256000.	3056500.	187.00	7.75	2.7	5.00- 7.50	,,	0.0	0.0	02.07.91	4	0.92
12	CHS12.LTH	UN 12*	BARCHAULI	254500.	3053250.	188.00	10.60	2.7	7.85-10.56	,,	8.2	77.1	23.01.91	4	2.72
13	CHS13.LTH	UN 13	KHAIRAHANI	259500.	3055750.	195.33	7.75	2.5	5.0 - 7.50	,,	4.7	61.3	29.07.91	4	2.17
14	CHS14.LTH	UN 14*	KAPIYA	261000.	3052500.	197.83	13.35	2.7	10.60-13.35	,,	10.9	81.8	25.01.91	4	2.79
15	CHS15.LTH	UN 15	BIRENDRANAGAR	263000.	3056000.	205.41	7.75	2.7	5.0 - 7.75	,,	4.4	56.8	26.07.91	4	1.34
16	CHS16.LTH	UN 16	BHANDARA	268000.	3056000.	216.80	8.00	2.7	5.25- 8.00	,,	6.5	81.2	26.01.91	4	3.60
17	CHS17.LTH	UN 17*	PIPLE	271000.	3053500.	229.00	13.40	2.7	10.65-13.40	,,	11.0	81.9	02.02.91	4	4.11
18	CHD01.LTH	NCD01	BHARATPUR	247200.	3065500.	200.00	100.00	42.0	34-40,46-64 70-82,91-97	Slotted	86.0	86.0	28.11.86	10/6"	-

(m) Meter

(1) Well with pumping tests have an *

(2) X and Y coordinates are taken from the 1:500,000 map of Nepal, a composite of LANDSAT imagery [National Remote Sensing Center (NRSC, 1984)].

(3) The absolute elevation of the well above is in terms of the mean sea level.

The 18 wells listed in Table 5 are further analyzed to Table 6. The percentage of aquifer (permeable) material found in each well and for all wells is listed in Table 7.

TABLE 6. *Analysis of Well Data in Table 5.*

Item	For UN-STW	For DTW	All together
Total no. of wells	17	1	18
Total drilled depth	173.8 m	100.0 m	273.8 m
Average depth per well	10.2 m	100.0 m	15.2 m
Total screen used	49.2 m	42.0 m	91.2 m
Average screen used	2.9 m	42.0 m	5.1 m
No. of wells with screen	17	1	18
No. of wells without screen	0		0

TABLE 7. *Analysis of Permeable Thickness from Table 5.*

Item	For UN-STW	For DTW	All together
Depth of calculation	40.0 m	40.0 m	40.0 m
Cumulative depth	173.8 m	40.0 m	213.8 m
Total permeable thickness	122.3 m	26.0 m	148.3 m
Average percent of permeable thickness	70.4%	65.0%	69.4%

3. HYDROLOGIC PROPERTIES OF WATER-BEARING MATERIALS

The quantity of water available from an aquifer depends on the ability of the aquifer to store and to transmit water. The ability of an aquifer to store water is measured by its storage coefficient (S) and the ability to transmit water by its transmissivity (T).

3.1 Pumping Tests

Six pumping tests in the Project wells were nominally successful (Figure 10). The pumping tests are of marginal quality and the numeric results they provide should be used with caution. The aquifer tests were analyzed by pumping test programs developed by UN/DTCD to determine the storage coefficient and the transmissivity of the Chitwan Dun valley aquifers. A comparison of the non-leaky theory of Theis and Jacob and the leaky-aquifer theory of Hantush was made with GWS. The Theis interpretation gave the best fit for all six UN wells. The results are listed in table 8 and the graphs are shown with observed data points with a computer-fitted curve in Appendix C.

Table 8. Hydrologic properties of pump tested project wells.

Well No.	Transmissivity (m2/day)	Saturated Aquifer Thickness (m)	Hydraulic Conductivity (m/day)	Aquifer Lithology	Discharge (l/s)	Static Water Level BGL (m)
UN 2	1216	4	304	GB	6	-2.8
UN 3	1127	8.3	135.8	GB	18.3	-0.6
UN 10	4628	7.5	617.1	GB	5	-2.6
UN 12	2312	7.9	292.7	GB	22	-2.7
UN 14	767	10.7	71.7	GB	16	-2.8
UN 17	6423	9.3	690.6	GB	22	-4.1

The T map, Figure 12, was prepared from the 6 pump test results. The map shows four zones of T in the project area. The highest T zone is found in the Central and extream Eastern part of the project area and the highest T value is in UN well 17 at Piple (6423 m2/day). The lowest T zone is found in the Eastern part of the project area and the lowest T value in UN well 14 at Kapiya (767 m^2/day).

Although pumping tests were done only in six UN wells, the discharge values were recorded in 14 UN wells. Thus, the yield potential map of the project area for Chitwan District was prepared from the discharge values of 14 project wells (Figure 13). The map shows four ranges of potential yield in the area including the location, discharge and static water level in the 14 wells. Central part of the project area have more than 20 l/s discharge and the largest potential yields. T values are highest in about the same area.

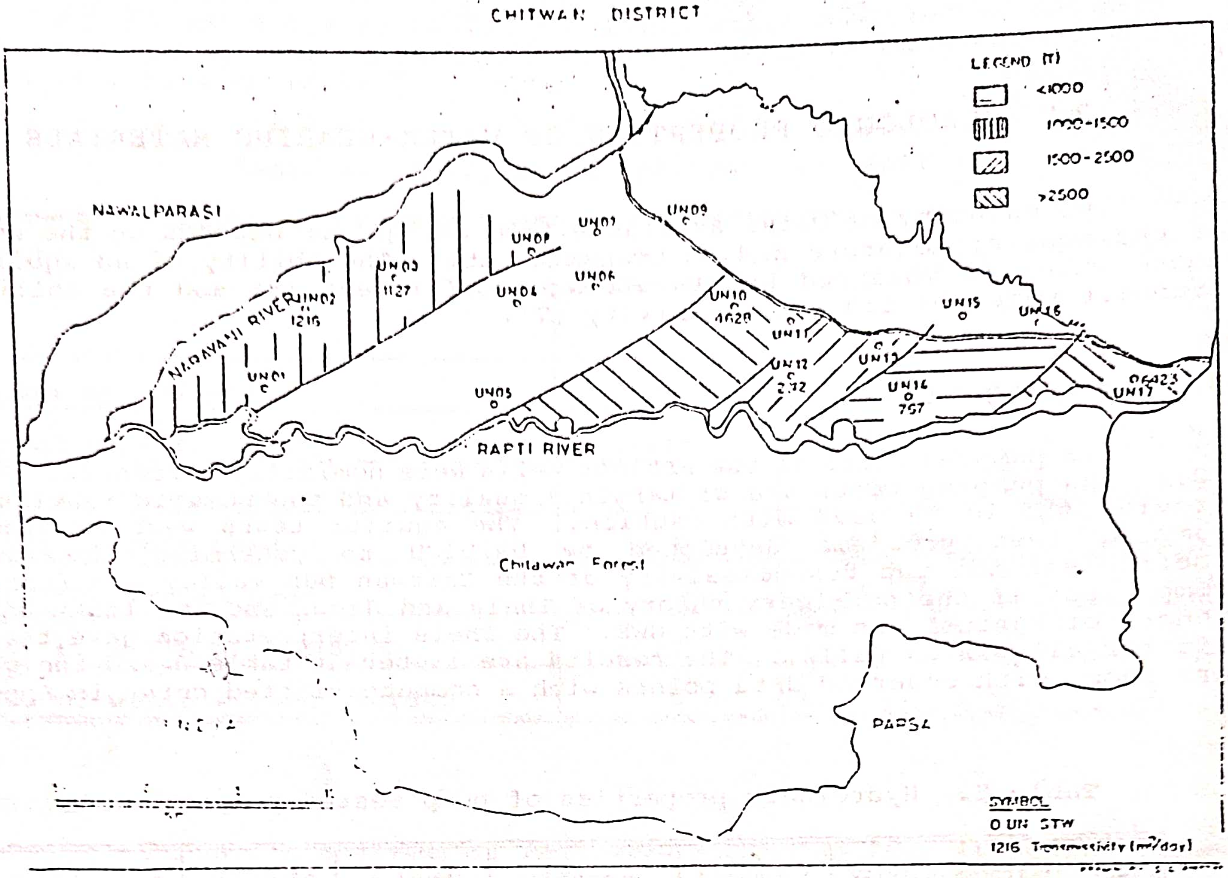


Figure 12. Map showing zones of transmissivity (m^2/day) in Chitwan.

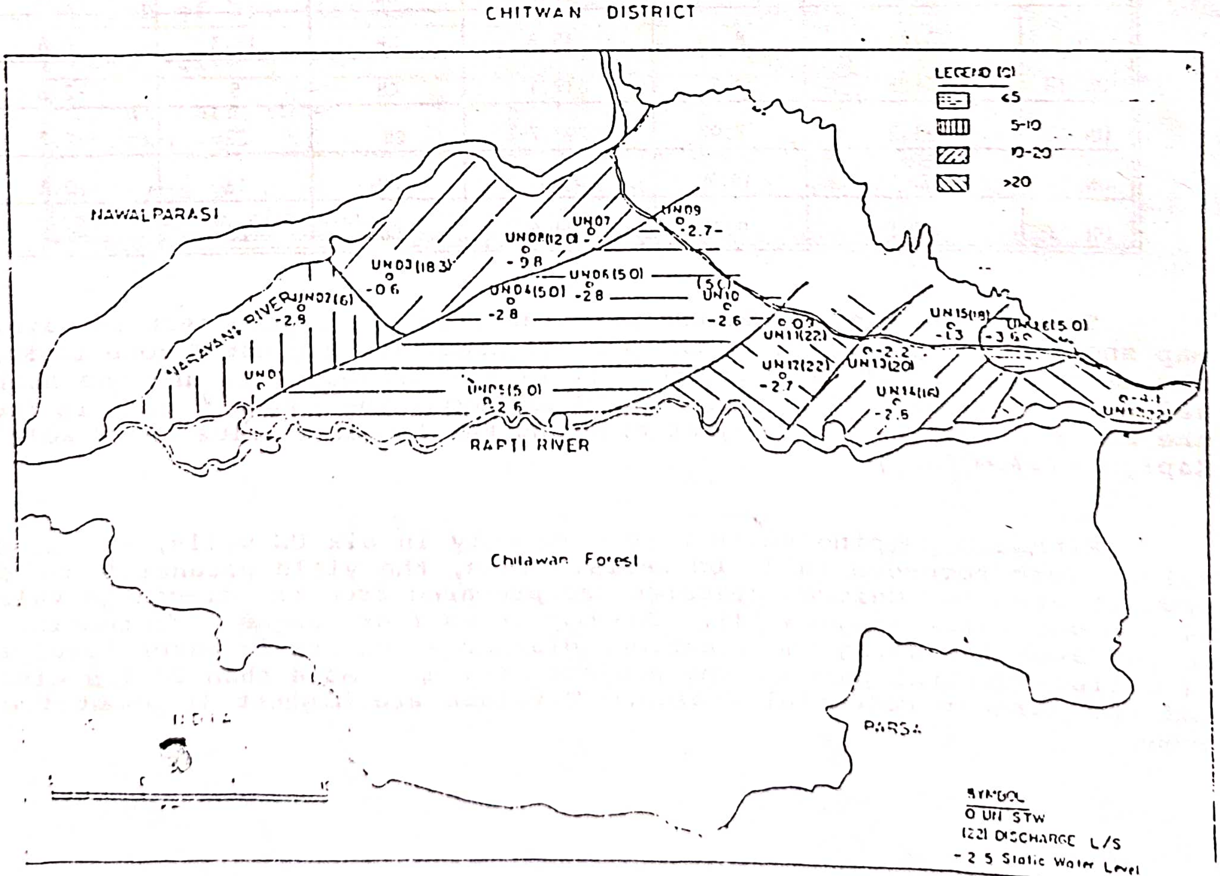


Figure 13: Map showing Zones of Yield Potential.

4. GROUND WATER

The discussion on ground water will cover general ground water concepts utilizing the data acquired and will be interpreted in this ground water investigation in Chitwan District as well as in the larger context of project NEP/86/025.

4.1 Source

The primary source of ground water in Chitwan District is local precipitation. For example, ground water in the Bhabar Zone of the Dun valley deposits is derived from precipitation that falls on Chitwan and the watersheds of the streams that traverse Chitwan, including the Siwalik areas of those watersheds. Ground water consists of precipitation that percolates through the materials on the earth's surface to the water table. Figure 14 illustrates the relationship between precipitation and water levels in selected wells.

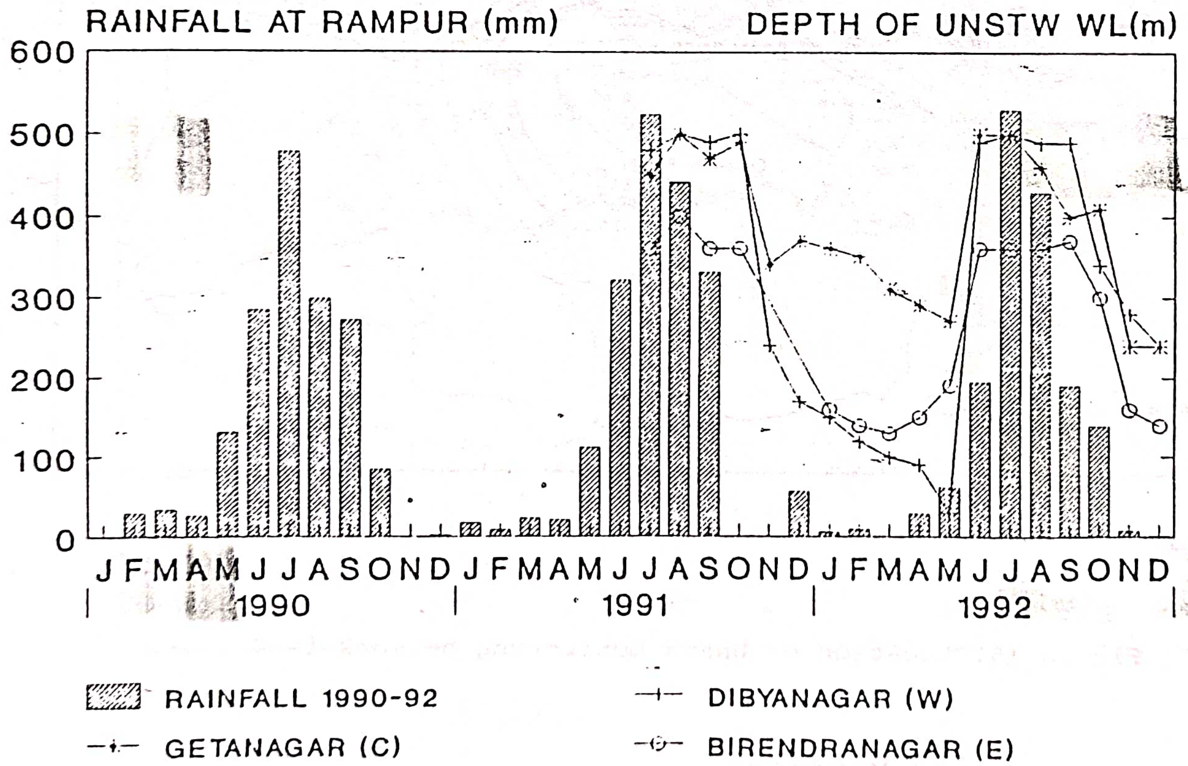


Figure 14: Relation between precipitation and depth to water table in the three selected wells fron East Central and Western part of the project area, Chitwan District 1990-1992.

4.2 Water Level Monitoring Network

A water level monitoring network is a major tool in ground water hydrology and regular measurement of water level in wells in a network are required for quantitative recharge and discharge calculations. Locations of wells in the monitoring network for Chitwan District are shown in Figure 15.

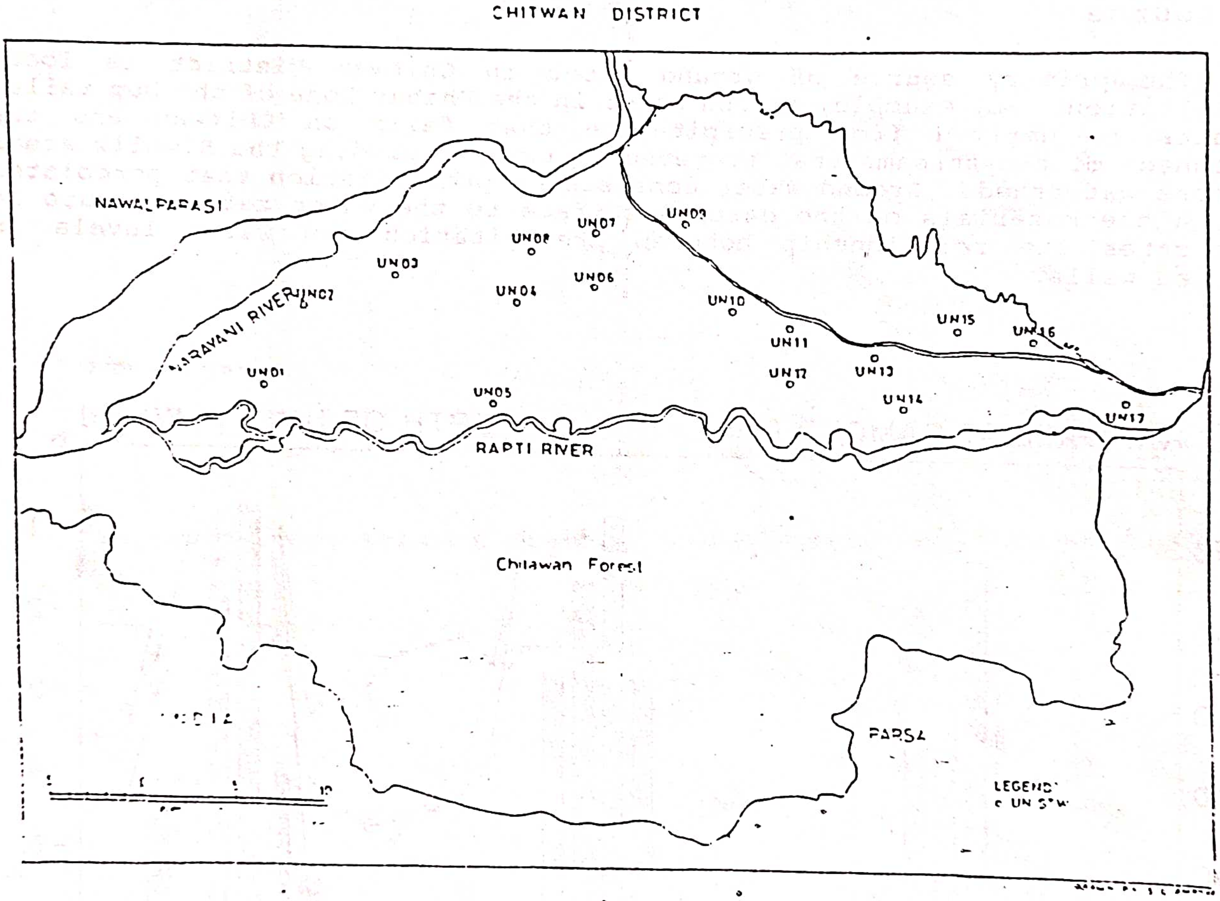


Figure 15. Location of UNSTW monitoring network in Chitwan.

4.3 Occurrence and Movement

Water in unconsolidated aquifers occurs in the interstices between rock particles. The rate at which water will move through these aquifers depends on the hydraulic gradient and on the shape, size, and the interconnection of the contained voids or interstices. The quantity of ground water available to wells depends on the areal extent and the saturated thickness of the aquifer. Interstices in sand and gravel are larger and better connected than interstices in silt and clay. Thus, water will flow freely through a coarse gravel under a low hydraulic gradient, but will move with extreme slowness through clay even under a high hydraulic gradient.

The shape and slope of the water table in September and December 1992 in Chitwan District are shown on Figure 16 and 17, and reflect post and pre monsoon respectively, by contours drawn through points of equal altitude of the water table. Ground water moves down gradient at right angles to the contours. The contours indicate that ground water was moving generally from Northeast to Southwest flowing towards Narayani River. The spacing of the contours indicates a hydraulic gradient of about 3.0 meters per kilometer in the West to 2.0 meters per kilometer in the East.

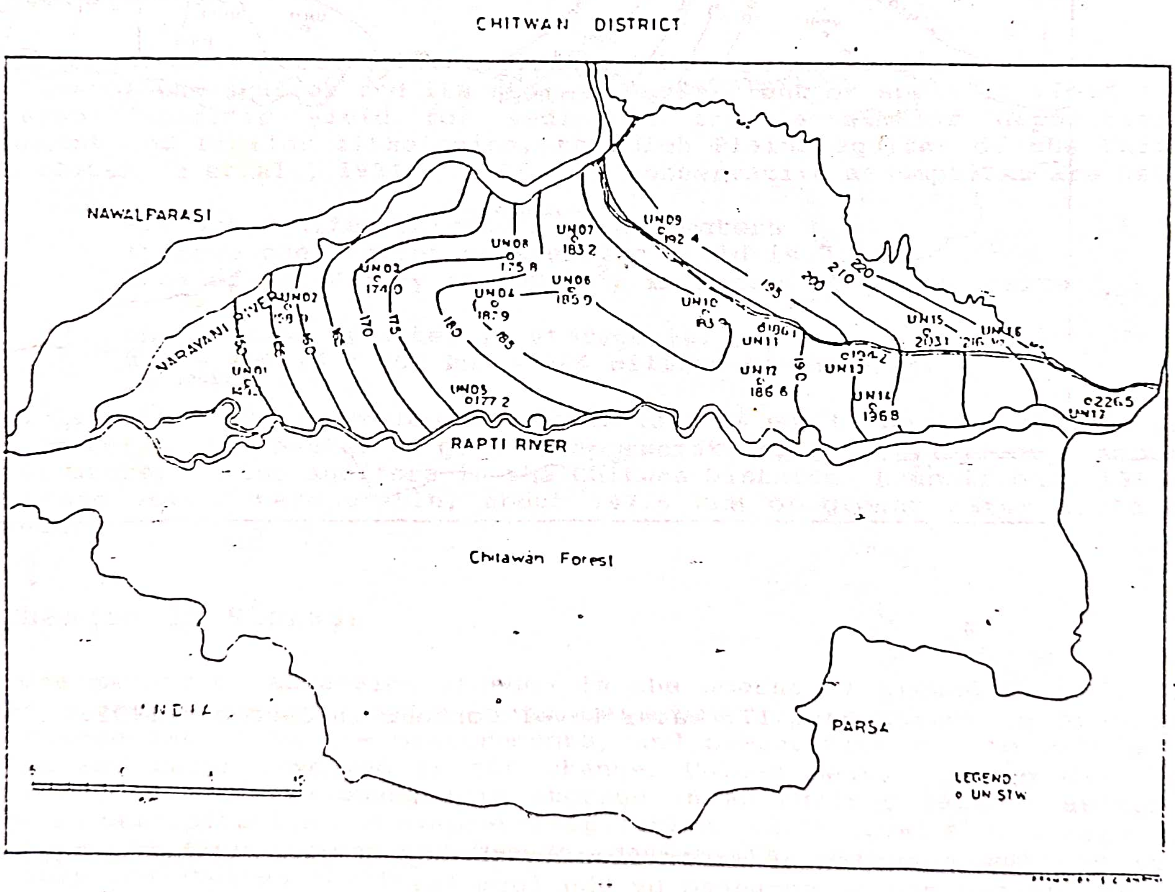


Figure 16. Water Level Contour in September 1992.

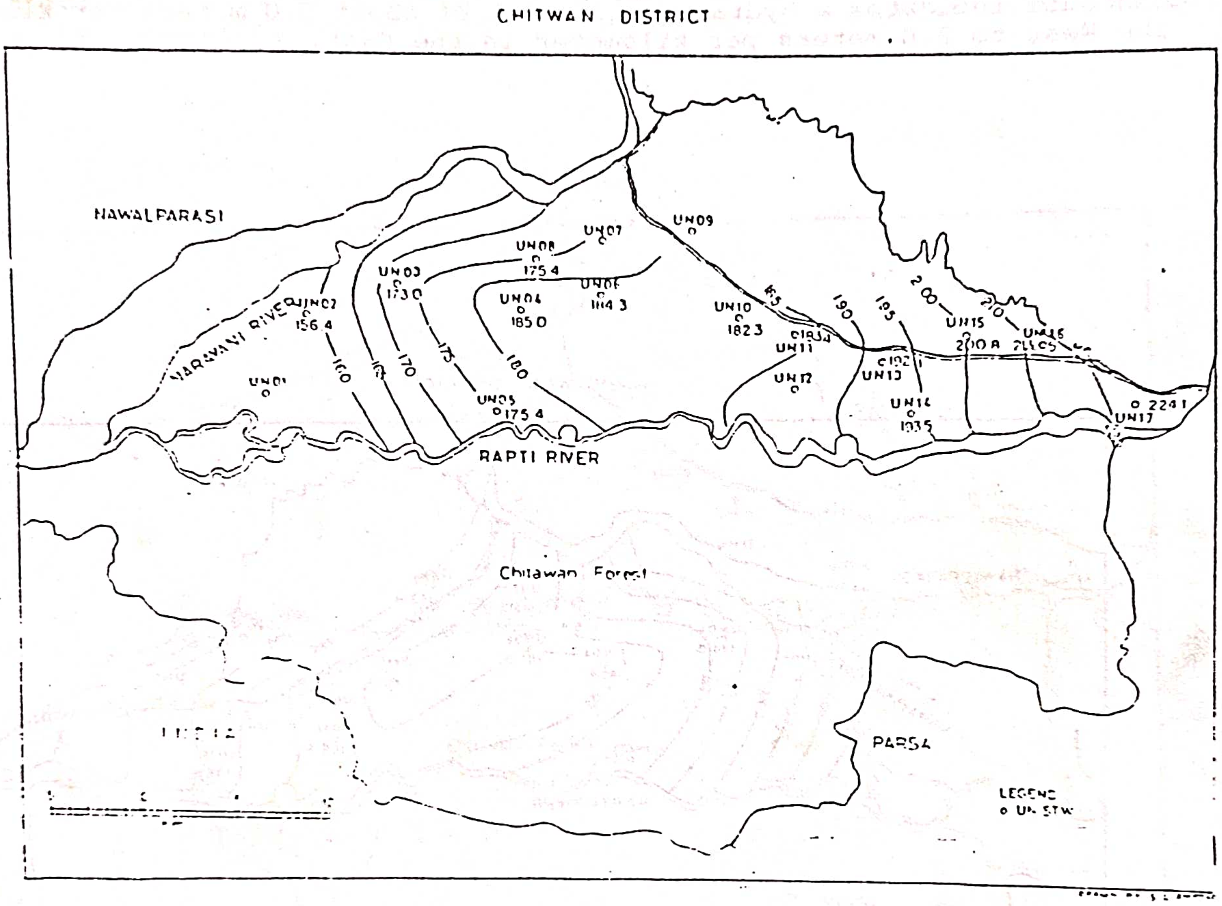


Figure 17. Water Level Contour in December 1992.

The quantity of water flowing through a given cross-sectional area of an aquifer can be computed by the formula:

$$Q = pAv = KIA = TIL$$

where Q is the quantity of water,
p is the porosity of the aquifer material,
A is the cross-sectional area,
v is the average velocity of ground water,
K is the hydraulic conductivity, and
I is the hydraulic gradient.
T is the transmissivity
L is the length

The approximate rate of movement of ground water through an aquifer is obtained by transposition of the above formula to:

$$v = KI/p$$

The major flowing trend of groundwater is toward Narayani River (Fig. 16). Therefore, an estimate of the quantity of water moving as subsurface outflow to Narayani River is calculated using the following assumptions:

Average aquifer saturated thickness is the average % of coarse grained material in the STW, or 69.4% of 40 meters, i.e. 27.8 meters.

Assumed effective porosity for sand and gravel is 15%,
Aquifer width (distance along Narayani River) 36 km,
Hydraulic gradient is 0.002 (or 2.0 meter per kilometer),
Transmissivity near Narayani River is 1172 (Ave.) m^2/day
Hydraulic conductivity near the river (T/Aqui.thickness) 133 m/day

The volume of water flowing to Narayani River
= 84,384 m^3/day
= 30.4 MCM/year at a rate of 1.77 m/day.

4.4 Storage

The amount of recoverable water stored in an aquifer is a function of the volume of the aquifer and its storage coefficient or specific yield (s). An average specific yield for sediments from a similar depositional environment and similar lithologies, the High Plains aquifer of the United States (Gutentag et.al., 1984), is 15. If conservative assumptions are used:

average aquifer thickness is 8.2 meters
storage coefficient or specific yield is 0.15
area of Dun Valley is 800 km^2, including Bhabar deposits

then volume of water in storage is:
8.2 m * 0.15 * 800 km^2 = 984 million m^3 (MCM)

This estimated volume of water in storage is not to be used as a figure for exploitation but rather to give an appreciation of the very large amount of water stored in the aquifers in the Chitwan District. Even if only 15% of the storage volume were usable, about 147.6 MCM of ground water would be available.

4.5 Changes in Storage

One method of assessing changes in the amount of ground water in an aquifer involves periodic water-level measurements, construction of water level change maps from the measurements, and computation of the volume of material and water involved in the change. Unless heavy pumping disturbs natural conditions, the changes in storage in an aquifer reflect seasonal changes in precipitation and evapo-transpiration. Water level change maps may show, by minor fluctuations and trends, essentially static conditions in a relatively undisturbed aquifer.

The table of water levels in project STWs is presented in D-1 of Appendix D. The fluctuation of the water table in the project wells in 1992 is presented in D-2 of Appendix D.

The location map and hydrographs of 12 wells are presented in Appendix E. The wells have a similar responses to the monsoon. Most of the monitored wells showed the maximum depth to water table in the month of December. The quick response of the water level to rainfall is logical and expected.

4.6 Discharge

Ground water in the valley portion of the Chitwan District is discharged from the aquifer by wells, evapo-transpiration, subsurface outflow (more or less equivalent to inflow to Narayani River, in case of Chitwan Dun Valley).

Measured data about these methods of ground water discharge are not plentiful and not of the best quality. Therefore, conservative estimates of well discharge are made to provide considerable stress on the aquifer. The subsurface outflow from the district was determined in the section 4.3 (occurrence and movement of ground water).

4.6.1 Pumping By Wells

Pumpage records for irrigation wells are not available and there is no project for acquisition of pumpage. However, an estimate of pumpage based on number of irrigation wells, average discharge, and hours pumped is calculated. The number of ADBN STW is 224 in 1991/1992 (GDC Inception Report, March 1993) and an increased number is estimated at 250. In addition there is one DTW. An estimate of potential pumpage from 251 wells with an average estimated yield of 15 l/s pumped for 2160 (6hrs/day) hours each year results in the following:

$$\frac{251 \text{ wells} * 2160 \text{ hrs} * 60 * 60 * 15 \text{ l/s}}{1000} = 29.3 \text{ MCM per year.}$$

4.6.2 Evapotranspiration

Direct evaporation occurs in areas where the water table is near the land surface, such as along stream banks and in stream beds. Also, during and immediately after the monsoon period the water levels are at or near the surface at many places in Chitwan, and the evaporation is considerable. The potential for evaporation is again high during the rice growing season as the paddies are really large bodies of surface water during that time. The average annual pan evaporation in Chitwan is estimated at 1500 mm, which is quite high.

Transpiration by plants from the saturated zone is not confined to the water courses where large vegetation may be found. Rather, transpiration is occurring in the forests, and from growing crops as well. The former extended forests of the Terai transpired large quantities of water (from a ground water source during the dry season) to the atmosphere. Forested areas are being converted to agricultural use but the volume of water transpired due to differences in vegetation is probably not appreciably different.

An estimate of potential evapotranspiration was made using the water table fluctuation between pre- and post- monsoon periods over the district. This assumes the principal cause of fluctuation to be loss of ground water due to evapotranspiration. The average fluctuation over the district is estimated at 2.5 m with 2.0 m of the fluctuation attributed to evapotranspiration, the specific yield of the saturated sediments is estimated at .15 and the area of Chitwan Dun Valley is 800 km^2. Thus, the ground water potentially evapotranspired each year is:

$$2.0 \text{ m} * .15 * 800 * 1000 * 1000 = 240 \text{ MCM}$$

Lowering the water table below the depth of most evapotranspiration processes would effectively permit the 240 MCM of ground water potentially evapotranspired each year to become recharge. This additional recharge would be available to irrigate crops.

4.7 Recharge

The aquifer in Chitwan is recharged by subsurface inflow from stream valleys entering the district, by subsurface inflow from the Siwalik Hills, by seepage losses from streams during high flow and perennial streams and by precipitation percolating directly through the soil and rock materials on the surface to the water table. These four increments of recharge result from local precipitation.

4.7.1 Subsurface Inflow

No data were obtained to provide a basis for a quantitative determination of subsurface inflow to the aquifer.

4.7.2 Seepage Losses From Streams

The drainage systems in Chitwan carry large amounts of surface water in, across and out of the district. Seepage to the aquifer is substantial during high flow. However, no quantitative determination of seepage into the aquifer was attempted.

4.7.3 Percolation From Rainfall

Percolation of precipitated water into the aquifer is the primary recharge mechanism in Chitwan District. The Bhabar Zone is particularly receptive to direct percolation to the water table due to the large size of the particles comprising the deposits. However, the main valley area is also receptive to direct percolation to the aquifer. Finally, the Siwalik exposures may contribute additional recharge through percolation to the aquifer and subsequent subsurface inflow to the valley aquifer.

Three estimates of recharge from precipitation are calculated. The first method utilizes data from Duba (1982); the second method assumes 10% (conservatively) of rainfall becomes recharge; the third method assumes a specific yield or effective porosity. Each method uses an area of 800 km^2 for the Chitwan Dun Valley.

<u>Method 1:</u>
Duba (1982) estimated 31% of the rain that falls on the Bhabar and 18.8% that falls on the Terai plain in the Nayani Zone would percolate to the aquifer. In Chitwan Dun Valley, there is no Terai Region and it is equivalent to Bhabar Zone. However, the estimate of recharge was made by Duba considering the estimated rainfall on Bhabar Zone.

Recharge in m^3/year = Annual precipitation in meters * area of recharge in Km^2 * % of rainfall to aquifer
= 1.7 m * 800 * 1000 * 1000 (i.e. 800 Km^2) * 31%
= 421.6 MCM

<u>Method 2:</u>
A more conservative estimate of recharge may be calculated by taking 10% of the average annual precipitation and assuming it will recharge the ground water reservoir. The calculation is ;

Recharge = 1.7 m * 800 km^2 * 10% = 136 MCM/year.

<u>Method 3:</u>
Assume the storage coefficient or specific yield is 0.15 (i.e. assuming 15% for the saturated thickness) in Chitwan and the monsoon water level fluctuation is 2.5 m over an area of 800 Km^2. The calculation is:

Recharge = 0.15 * 2.5 m * 800 Km2 = 300 MCM/year

These estimates do not take into account rejected recharge due to soil saturation nor the increase of recharge possible if water levels were lowered by pumpage for irrigation below the depth of most evapotranspiration losses.

The difference between a potential recharge of more than ~~142~~ 421 MCM per year and subsurface outflow into Narayani River of about 30.4 MCM per year is very large. The excess potential recharge is considered to be discharged through evapotranspiration (dominant component), inflow to streams (minor component) and also withdrawals from the aquifer by wells (minor component).

4.8 SUMMARY OF GROUND WATER SYSTEM

The indeterminate number of interconnected aquifers in the Chitwan Valley are subject to recharge (addition of water to the aquifers), storage (retention of water in the aquifers), and discharge (diversion of water from the aquifers). The relation is simple and direct. When recharge exceed discharge, (during monsoon period) the quantity of water in storage increases and the water table rises. Conversely, when discharge exceeds recharge, (during dry period) the quantity of water stored decreases and the water table declines. The monsoon raises the water table as the aquifer(s) are recharged by percolation of rain, seepage from streams and by subsurface inflow from the Siwaliks. The dry season lowers the water table as the water is pumped, transpired, evaporated, and moves in the subsurface toward the west.

The water level change maps may reflect the recharge, change in storage and discharge taking place in the chitwan ground water system. The change maps indicate the system is maintaining equilibrium as agricultural practices replace the forests. Put another way, stress on the aquifer, for the short period of record of this project, shows no discernible effect on the water level maps.

The storage estimate, recharge estimates, the pumpage estimate and estimate of outflow to Narayani River seem reasonable. Table 9 brings these figures together. The estimate of water in storage is a large number but only part of that would provide water to wells. However, about 147.6 MCM of ground water could be used if only 15% of the estimated storage is available.

TABLE 9. Storage, recharge and discharge estimates of ground water in Chitwan.

Item	Storage	Recharge per year	Discharge per year
Volume of water (Static reserve)	984 MCM its 15%=147.6		
Recharge by 3 methods: 1) Duba's estimate 2) Conservative estimate (with 10% of rainfall) 3) Calculation considering effective porosity, & fluctuation of W.T.		 422 MCM 136 MCM 300 MCM	
Pumpage			29.3 MCM
Outflow to Narayani River			30.4 MCM
Evapotranspiration			240 MCM

Information about the recharge, storage and discharge in the ground water system in Chitwan District is not complete. Several of the components necessary to fully describe the system have not been measured or observed. However, estimates are made for some major components where data are lacking with the thought that the estimates may be refined as additional data are collected in the future; and other components are not known and not estimated as their influence will become measurable as the ground water system is developed. The status of data components required to describe the Chitwan ground water system are listed in Table 10.

TABLE 10. *Status of components required to describe Chitwan Ground Water System.*

COMPONENT	AVAILABLE	M=measured E=estimated	RELIA-BILITY	AREAL DISTRI-BUTION
Siwalik information	No			
Bhabar Zone delineation	No			
Terai Plain delineation	No			
Detailed well inventory	No			
Lithology of wells	Yes	M	Adequate	Adequate
Aquifer tests	Yes	M	Poor	Poor
Storage coefficient	Yes	E		
Transmissivity	Yes	M	Poor	Poor
Leakage	No			
Water level measurements	Yes	M	Adequate	Adequate
Weather records	Yes	M	Adequate	Adequate
Pumpage records	Yes	E		
Stream flow records	No			
Evaporation data	No			
Transpiration data	No			

5. SHALLOW GROUND WATER AVAILABILITY

Areal delineation of probable SIW is a major goal of the present project. The criterion defining a SIW are listed below:

1. a water level that does not exceed 7 meters in depth in the dry season while pumping
2. a discharge adequate to irrigate an individual farm, as required
3. no deeper than 50 meters
4. 100 mm or 4 inches in diameter
5. use a centrifugal pump
6. powered by a diesel or electric motor
7. drilled by indigenous methods

The definition includes depth, diameter, energy source, types of pump and method of drilling a well all predicted to be within the range of resources a farmer may command.

Figure 18 shows the areas of probable SIW in Chitwan District. Contours of depth to water have not exceeded 5 meters during the dry season in the area shown since the project began. The depth to water criterions is the most important hydrologic constraint in the above definition of the SIW. Wells in the valley will almost always find water but the wells may not yield water to a centrifugal pump during the dry season if the depth to water exceeds 7 meters. Three meters of drawdown must be exceeded before a well would cease to produce irrigation water in the designated areas.

Wells drilled to 40 meters should find about 28 meters of aquifer material, on average. This also means that some wells may find practically no aquifer and some wells may find practically all aquifer. In other words, holes will be drilled which will be unsuccessful wells because there is insufficient aquifer at that location.

The practice of drilling test holes to assist in choosing a productive location to place an irrigation well is common and frequently required in many ground water areas in many countries. The depositional environment of the aquifers in the Terai is such that very different lithologies may be encountered in two test holes within relatively few meters of each other. Thus, the map shows potential SIW area but does not guarantee success at each and every well located within this area.

Individual farms in Chitwan averaged about 1.7 hectares in area in 1981 (SPBN 1990). A well that pumps 3 liters per second could cover one hectare with about 5 centimeters of water in 48 hours. The average farm could be irrigated with such a well. However, it is questionable if average size farms in Chitwan are economic, even with the technology limited by the definition. The limiting factor, economically is the average size of a farm.

CHITWAN DISTRICT

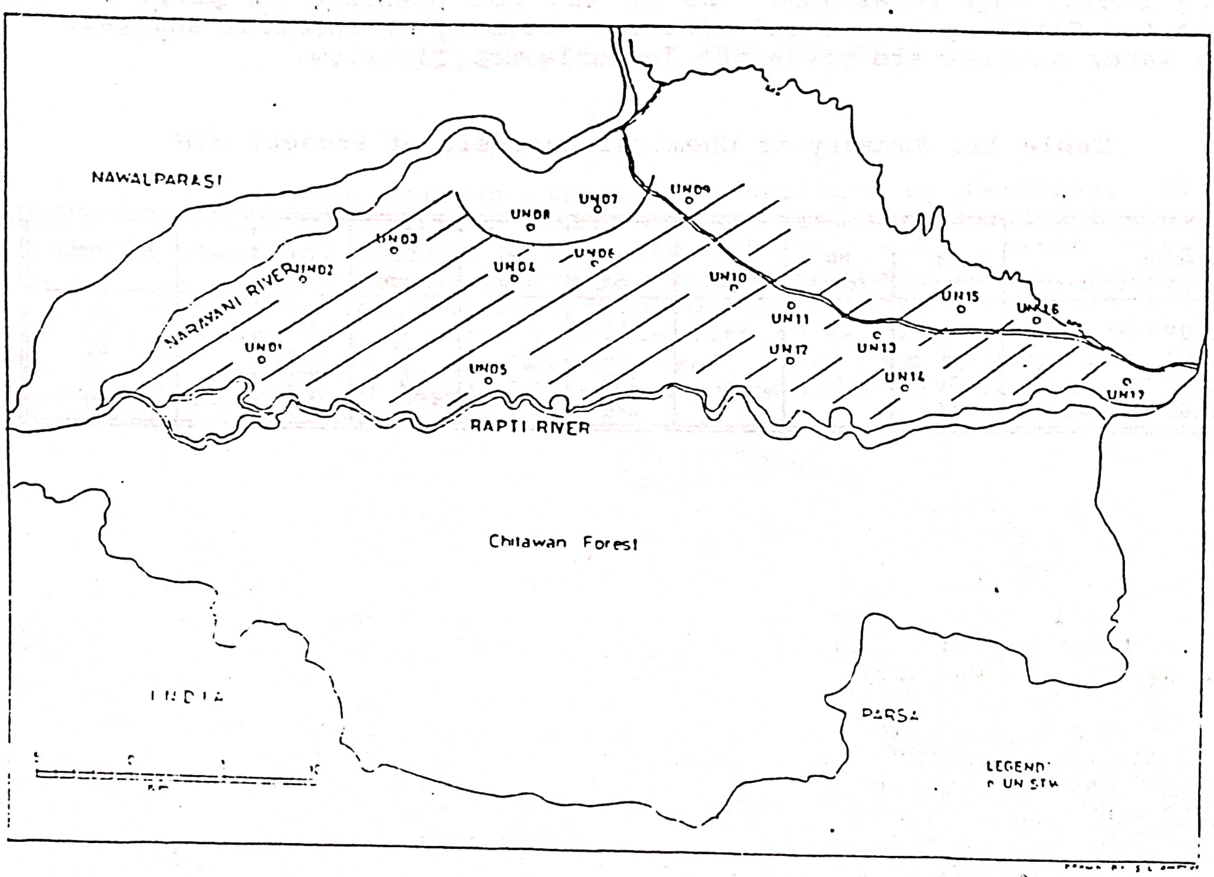


Figure 18. Shaded pattern area shows probable SIW area in Chitwan District.

6. ASSESSMENT OF WATER QUALITY

Four water samples collected from the project wells were analyzed in GWRDB laboratory in 1991. During the analyssis, there was no instrument to analyze Sodium and Potassium. So it was not possible to prepare Wilcox Diagram for Salinity hazard calculation. Summary of chemical analysis of the water samples are presented in Table no. 11 below.

Table 11. Summary of Chemical Analysis of Project STW.

Sample Identification	Ca [ppm]	Mg [ppm]	Na [ppm]	HCO_3 [ppm]	SO_4 [ppm]	Cl [ppm]	pH	SAR	Hardness
UN01 Meghauli	6	26	-	88	-	7	7.0	-	120
UN02 Dibyanagar	8	6	-	64	-	17	6.5	-	44
UN03 Bhimnagar	30	5	-	132	-	5	7.0	-	96
UN08 Prembasti	64	7	-	224	-	15	7.0	-	190

7. UTILIZATION OF GROUND WATER

Ground water in Chitwan District is utilized by families, villages, towns and schools for drinking water; for watering animals; for business and industrial purposes; but the largest use and the use that seems destined to have a large increase in the future is for irrigation of crops. According to the statistics from Table 4, only 30.3% of the potential irrigation land in Chitwan is irrigated the whole year, leaving 69.7% or about 29.237 hectares that could be irrigated the whole year. The food requirements of the expanding population of Nepal will require more and more year round irrigation in the Terai and therefore in Chitwan.

8. SUMMARY AND RECOMMENDATIONS

8.1 Summary

The study of the shallow ground water resource of Chitwan District is part of a study of ground water throughout the Terai. The project, NEP/86/025 is a cooperative effort by the United Nations Department of Technical Co-operation for Development and the Ground Water Resources Development Board, HMG, Nepal.

Field work for this report began in the January 1987 and for the most part was completed in 1991. The work consisted of drilling wells, making water level measurements, lithologic determinations, altitude surveys of land surface at wells, and aquifer tests.

Sixteen manually drilled wells and one well by rig were completed. The average depth of the wells was about 10.2 meters. Slightly more than 70.4% of the sediments encountered were sand, gravel and boulder and are considered an aquifer.

Six pumping tests were completed and the range of transmissivities is from 767 to 1216 m^2/day.

The water level monitoring network progressed from dug wells in 1987 to project STW in 1991. As expected, the wells have the deepest water levels just prior to the monsoon and the shallowest water levels just after the monsoon. Water level contour maps indicate the ground water flows from East to West towards the Narayan River with a gradient of about 3.0 meters per kilometer in the East and about 2.0 meter per kilometer at the West.

The aquifer in Chitwan is recharged primarily by precipitation percolating directly through the soil and rock materials on the surface to the water table. The Bhabar Zone is particularly receptive to direct percolation to the water table because of the large size of the particles comprising the deposits. However, the Chitwan Dun Valley is also receptive to direct percolation of precipitation to the aquifer. As much as 421 MCM per year may potentially be available for recharge although a more conservative estimate of about 136 MCM is also calculated. Even the latter estimate compares favorably with the 30.4 MCM of water flowing to Narayani River per year.

The water level change maps reflect the recharge, change in storage and discharge taking place in the Chitwan ground water system. The water level change maps indicate that the system is maintaining equilibrium as agricultural practices replace the forests. Put another way, stress on the aquifer, for the short period of record of this project, shows no discernible effect on the water level maps.

8.2 Recommendations

Ground water in Chitwan district is utilized by families, villages, town and schools for drinking water, for watering animals, and for business and industrial purposes, but the largest use and the use that seems destined to have a large increase in the future is for irrigation. This report provides valuable data for planning and continuing development of the ground water resource but large scale development in a specific area should include additional investigative wells and properly designed and completed aquifer tests to help maximize success.

9. GLOSSARY OF TERMS

Aquifer: A rock formation, bed, or zone that contains water that is available to wells. An aquifer is sometimes referred to as a water-bearing rock, or water-bearing bed.

Evapotranspiration: The combined total water evaporated by heat energy and transpired by plants into the atmosphere.

Gaining stream: A stream or reach of a stream whose flow is being increased by inflow of ground water. Replaces the term "effluent stream."

Ground water: Water in the saturated zone or water below the water table.

Hydraulic conductivity: A measure of the rate of flow of water through an aquifer, which is dependent primarily on the nature of the interstices within the aquifer. Expressed in units of length per units of time that are consistent and suitable to the problem involved.

Hydraulic gradient: Gradient of the water table measured in the direction of the greatest slope, generally expressed in meters per kilometer.

Inflow: Movement of ground water into an area in response to a hydraulic gradient.

Interstice: An opening or void in a rock. Interstices may be filled with air, gas, oil, water, or some other material, The interstices in an aquifer are filled with water.

Outflow: Movement of ground water from an area in response to a hydraulic gradient.

Percolation: The movement of water through soil and rock to the saturated zone.

Permeability: The capacity of water-bearing rock or soil to transmit water, which is related to the size and interconnection of interstices. Replaced by the term "hydraulic conductivity."

Porosity: The porosity of a rock is its property of containing openings or interstices. Quantitatively, the porosity of a rock is the ratio (usually expressed as a percentage) of the volume of openings in the rock to the total volume of the rock.

Recharge: The process by which water is absorbed and added to the saturated zone. Also used to designate the quantity of water added to the ground-water reservoir.

Runoff: The discharge of water through surface streams. It includes both surface-water runoff and ground-water runoff. Also used to designate the quantity of water discharged as runoff.

Saturated zone: The zone of porous rocks saturated with water. Ground water is contained in this zone.

Specific yield: also called effective porosity (Johnson, 1967), is defined as the ratio of (1) the volume of water that the saturated sediment will yield by gravity drainage to (2) the total volume of saturated rock. Specific yield is expressed as a dimensionless fraction or percentage. Specific yield depends on particle size, shape, sorting, and cementation of the aquifer material and drainage time.

Specific retention: It is the difference between porosity and specific yield and is defined as the ratio of (1) the volume of water retained in the rock after gravity drainage to (2) the total volume of the saturated rock.

Storage: Water stored in openings in the saturated zone is said to be in storage. Discharge of water from an aquifer not replaced by recharge is said to be from storage.

Storage coefficient: The volume of water released from or taken into storage per unit surface area of an aquifer per unit change in the component of head normal to that surface.

Transmissibility: The transmissibility of a rock or soil is its capacity to transmit water under pressure. Replaced by the term "transmissivity."

Transmissivity: The rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient. Expressed in units of length squared per units of time. Replaces the term "coefficient of transmissibility." To convert a value for coefficient of transissibility to an equivalent value of transmissivity, multiply by 0.134.

Water table: The upper surface of the saturated zone where the pressure is atmospheric. The water table is not a plane surface, but has irregularities much like the land surface.

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APPENDIX A

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 collect field data to establish a ground water data base and to assess the development potential of shallow aquifers all over the Terai. The government counterpart agency is the Ground Water Resources Development Board (GWRDB) under the Department of Irrigation (DOI), Ministry of Water Resources, HMG, Nepal. The project began in June 1987.

The immediate objectives of project NEP/86/025 are:

(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 technical capacity of GWRDB with regard to exploration, assessment and development of ground water resources.

The following project outputs are anticipated:

(a) Computerized data base with about 2000 shallow water points from all over the Terai. This was expanded in December 1988 to include deep wells. Information on well location, lithology, hydrogeological parameters, water use, water levels, and etc.

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

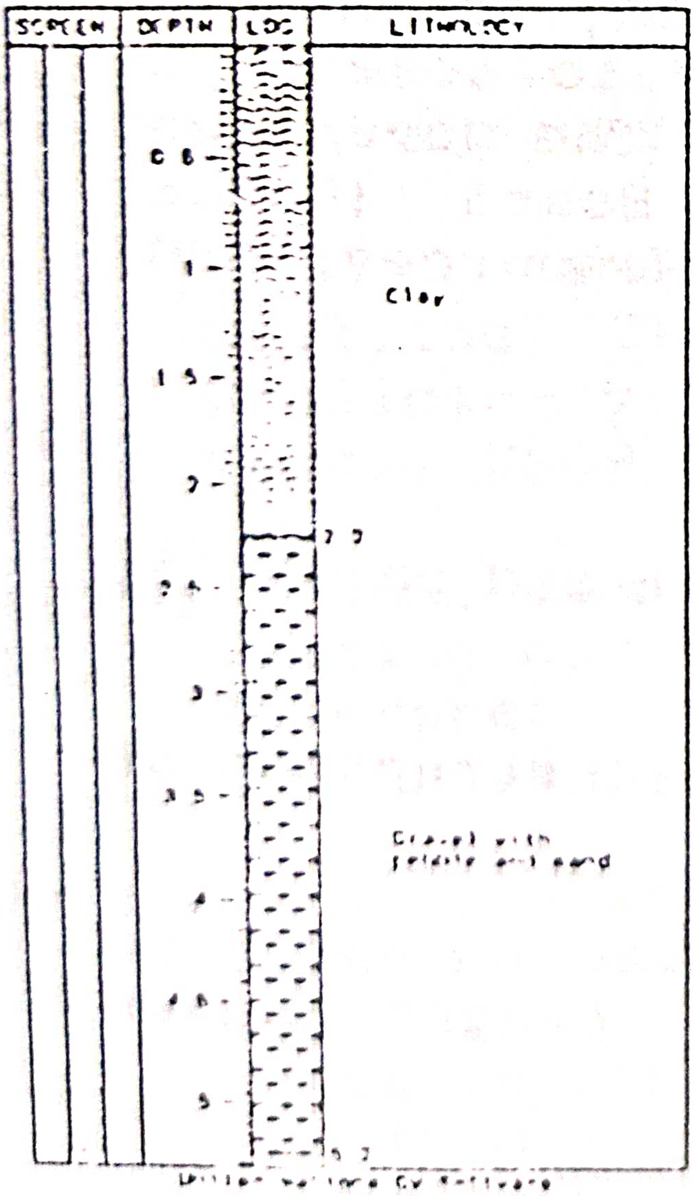
(c) Hydrographs (water level graphs) from selected observation points in a minimum period of eleven months.

(d) Reports on mathematical modelling.

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

Well No. UN 1	Location PARSADHAP (Meghauli)
Elevation 150.65	X = 22?250 Y = 3054000
Method of Drilling	MANUAL (Thokuwa), Boulders Zone
Drilling Dates	10.7.1991-13.7.1991
Total Depth	5.25
Comments	Well Size 4" M P 0.25 M Screen Position 2.5-5.25 Screen Type Perforated

WELL LOG



PUMPING TEST

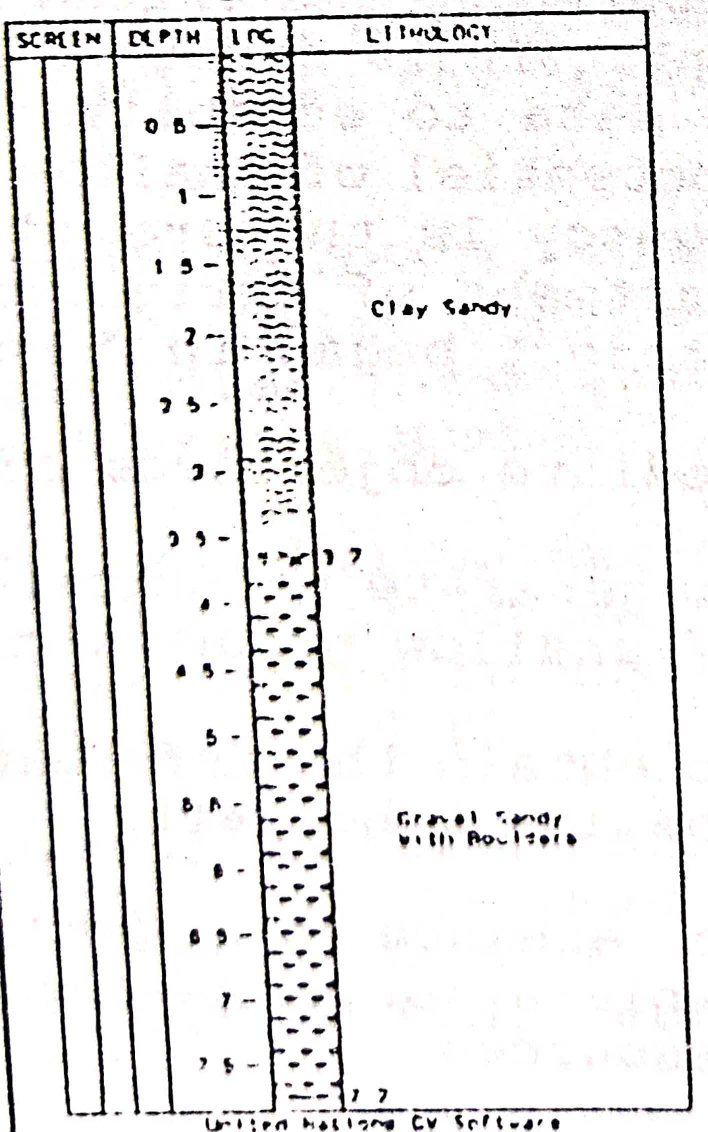
Capacity Not Available

Not Tested

B 1. Log of UN 1

Well No UN 2	Location DIBYA NAGAR
Elevation 159 95	x = 223500 y = 3058250
Method of Drilling	MANUAL (Thokuwa), Boulders Zone
Drilling Dates	8 7 1991-10 7 1991
Total Depth	7 75
Comments	Well Size 4" Dia M P 0 50 m Screen Position 5 0 - 7 75 Screen Type Perforated

WELL LOG



PUMPING TEST

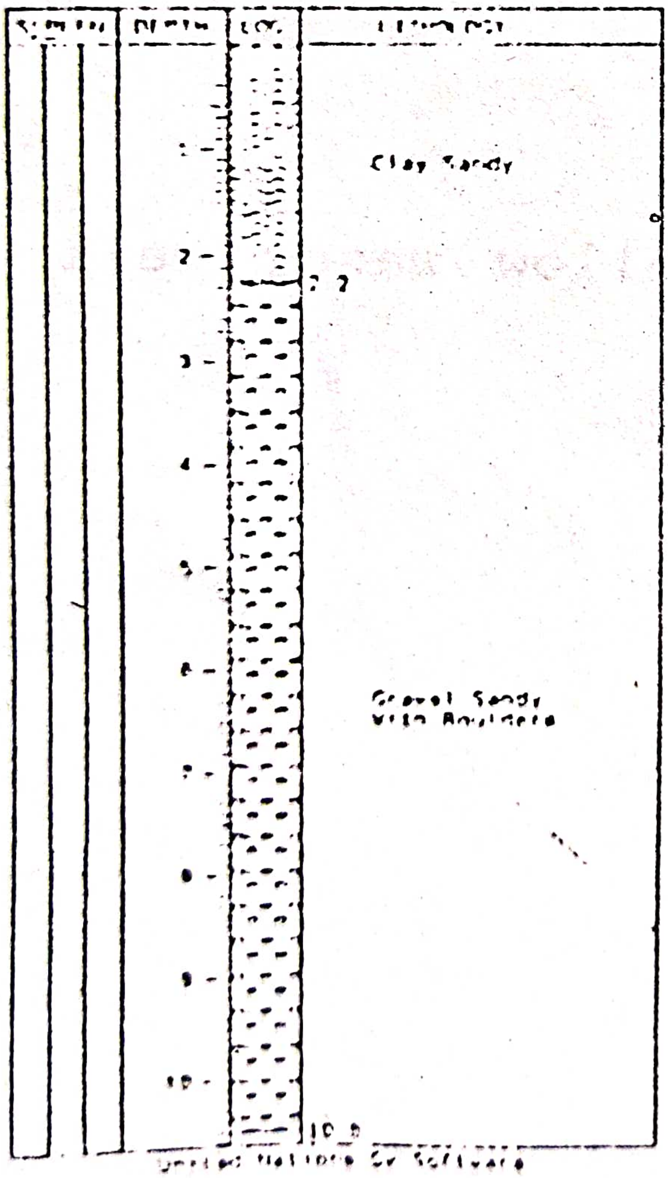
Date 12 7 1991
Capacity 6 l/s
Duration 120 Min
SWL 2 80 m b g l
DWL 4 31 m b g l

Pumping test was done with 4" Dia Centrifugal Pump

B 2. Log of UN 2

Well No UN 3	Location [illegible]
Elevation	X = 734250 Y = 3358500
Method of Drilling	Manual (Thokiwa) Boulders Zone
Drilling Dates	5 7 1991-7 7 1991
Total Depth	10 50
Comments	Well Size 4 Dia M P 0 80 m Screen Position 7 26 - 10 50 Screen Type Perforated

W E L L   L O G



PUMPING TEST

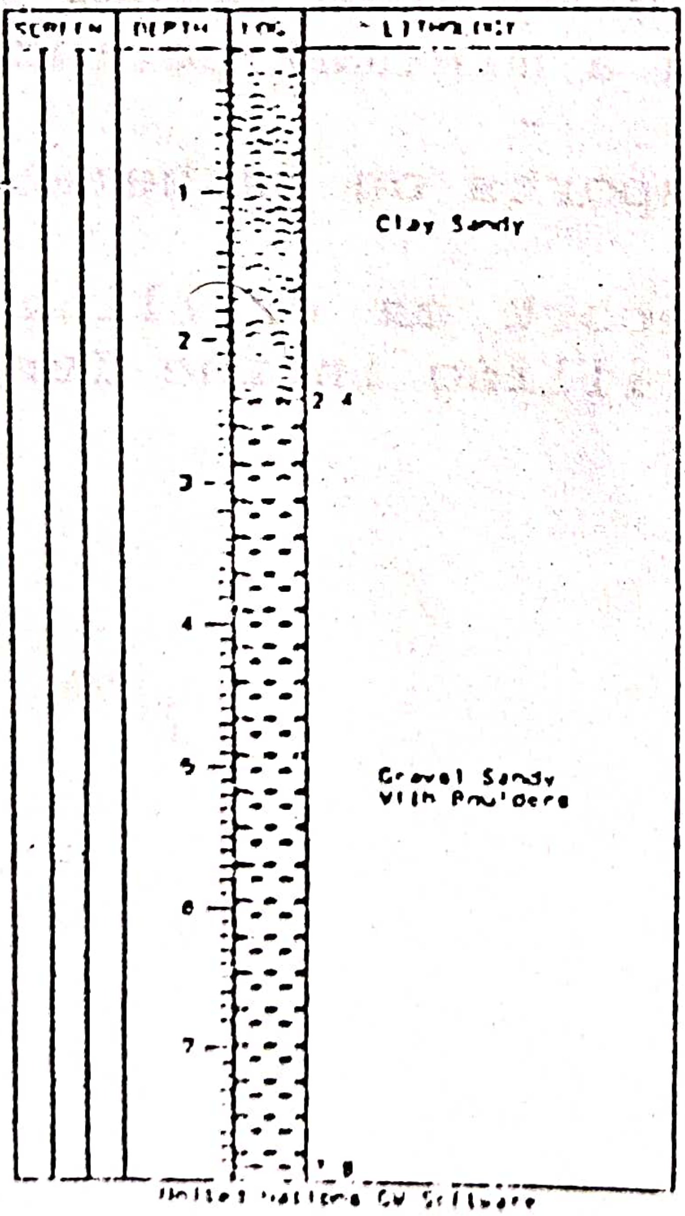
Date 10 7 1991
Capacity 18 33 l/s
Duration 120 Min
SWL 0 56 m b g l
PWL 4 07 m b g l

Pumping Test was done
with 4 Dia Centrifugal Pump

B 3. Log of UN 3

Well No UN 4	Location SHIVANAGAR
Elevation 188 20	x = 240500 y = 3058750
Method of Drilling	MANUAL (Thokuwa) Boulders Zone
Drilling Dates	17 1 1991-18 1 1991
Total Depth	7 85
Comments	Well Size 4"Dia M P 0 40 m Screen Position 5 10 - 7 85 Screen Type Perforated

WELL LOG



PUMPING TEST

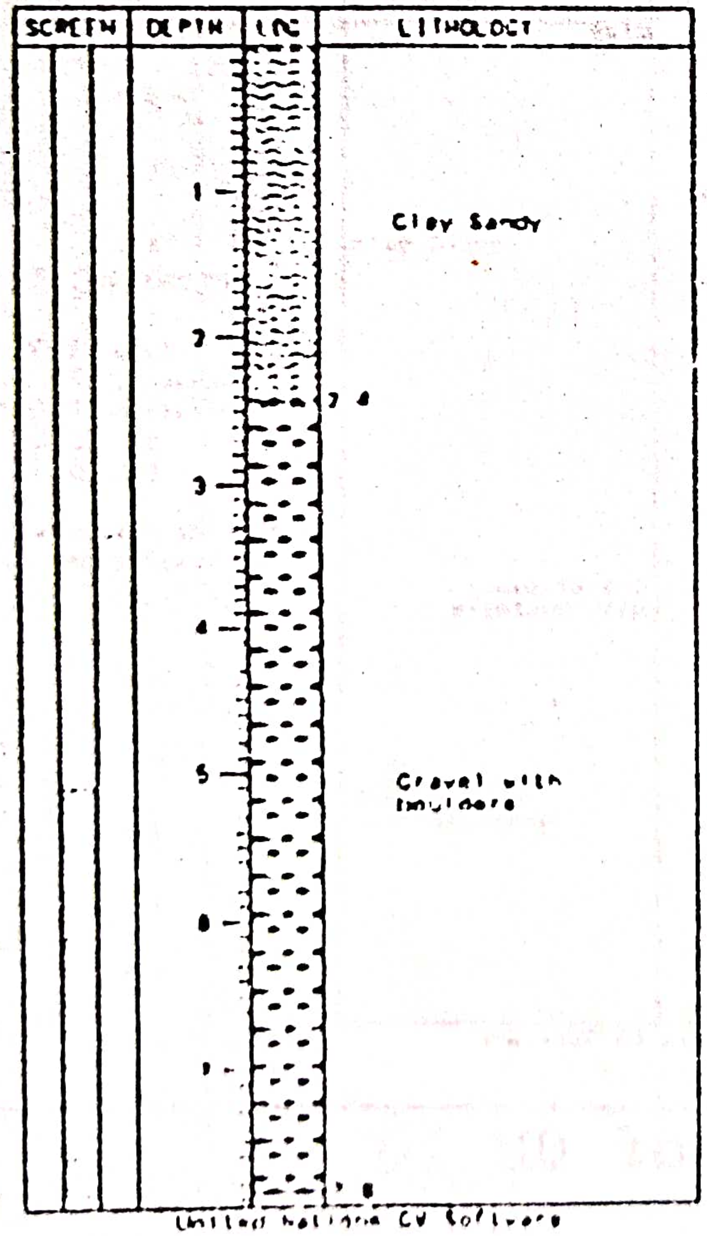
Capacity 5 l/s
SWL 2 80 m b g l
DWL 2 92 m b g l

Not Tested

B 4. Log of UN 4

Well No UN 5	Location PATHIHANI
Elevation 178 39	x = 239250 y = 3053005
Method of Drilling MANUAL (Thokuwa), Boulders Zone	
Drilling Dates : 21 1 1991-22 1 1991	
Total Depth : 7 85	
Comments : Well Size 4"Dia M P 0 10 m Screen Position 5 10 - 7 85 Screen Type Perforated	

WELL LOG



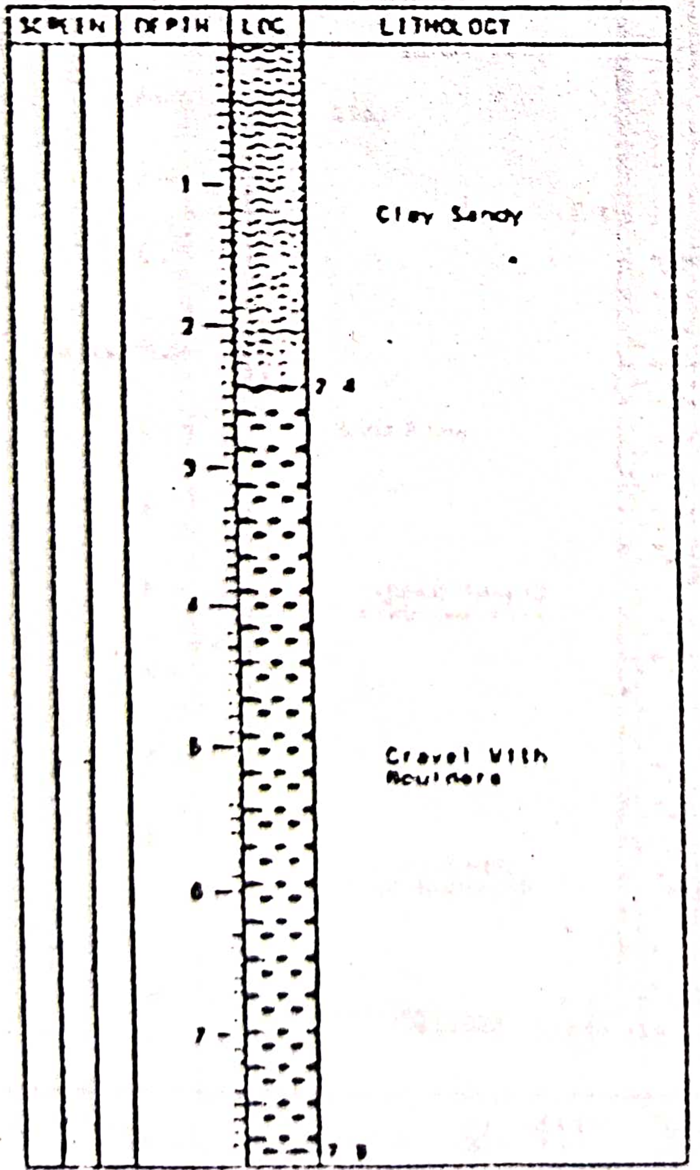
PUMPING TEST

Capacity 5 l/s
SWL 2 62 m b g l
DWL 4 0 m b g l

B 5. Log of UN 5

Well No UN 6	Location GEETANAGAR
Elevation 187 93	x = 243750 y = 3057750
Method of Drilling MANUAL (Thokuwa),Boulders Zone	
Drilling Dates 19 1 1991-20 1 1991	
Total Depth 7 85	
Comments : Well Size 4"Dia M P 0 40 m Screen Position 5 10-5 85 Screen Type Perforated	

WELL LOG



United Nations CV Software

PUMPING TEST

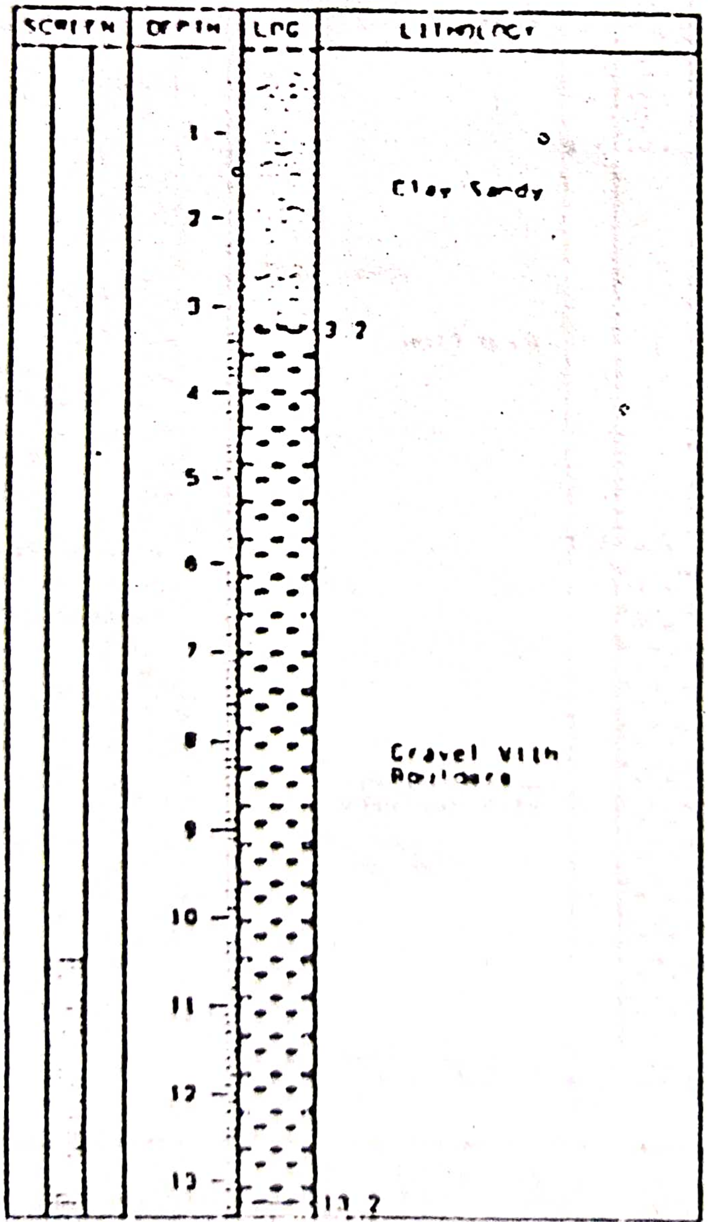
Capacity 5 l/s
2 79 m b g l
4 12 m b g l

Pumping test not performed

B 6. Log of UN 6

Well No UN 7	Location NARAYANPUR
Elevation 15.53	X = 245250 Y = 1062250
Method of Drilling	MANUAL (Thokuwa), Boulders Zone
Drilling Dates	12 1 1991-14 1 1991
Total Depth	13 25
Comments	Well Size 4"Dia M P 0 50 m Screen Position 10 5 - 13 25 Screen Type Perforated

WELL LOG

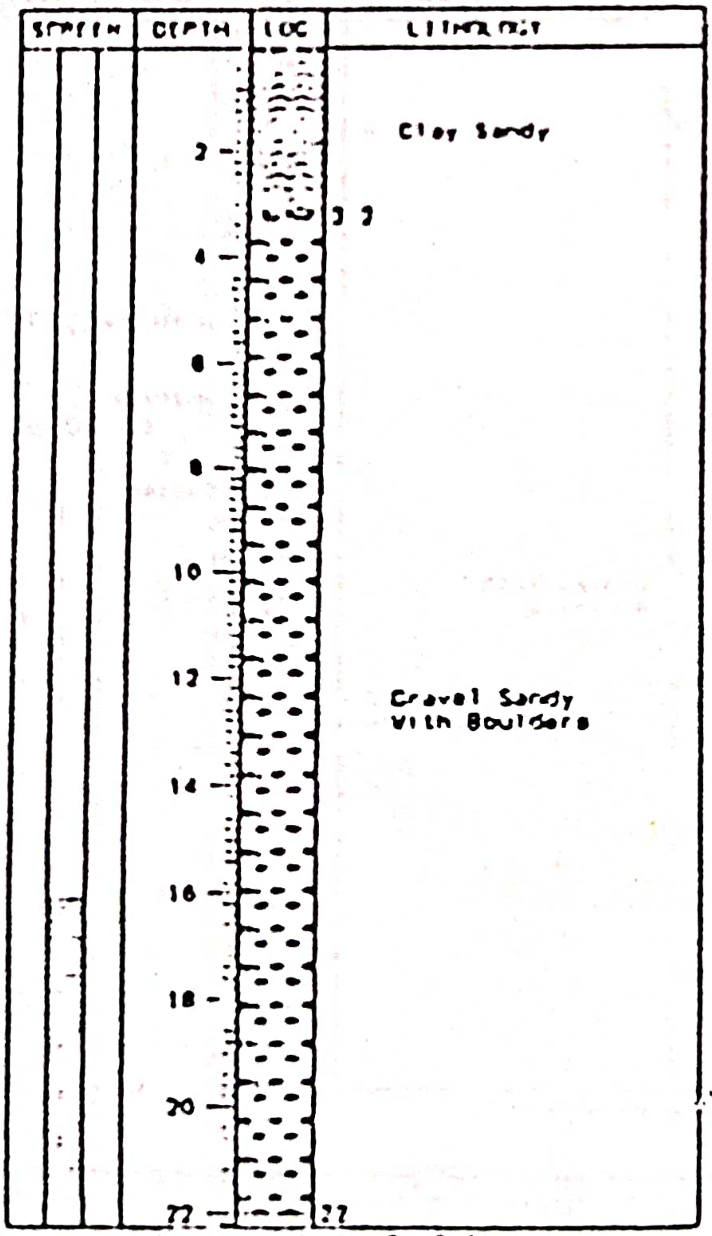


United Nations CV Software

B 6. Log of UN 7

Well No UN 8	Location PREMRASTI
Elevation [illegible]	x = 241500 y = 3061000
Method of Drilling	RIG, Boulders Zone
Drilling Dates	9 3 1991-16 3 1991
Total Depth	22 00
Comments :	Well Size 6"Dia M P 0 50 m Screen Position 18 10-24 60 Screen Type Slotted Pipe

WELL LOG



United Walling CH Software

PUMPING TEST

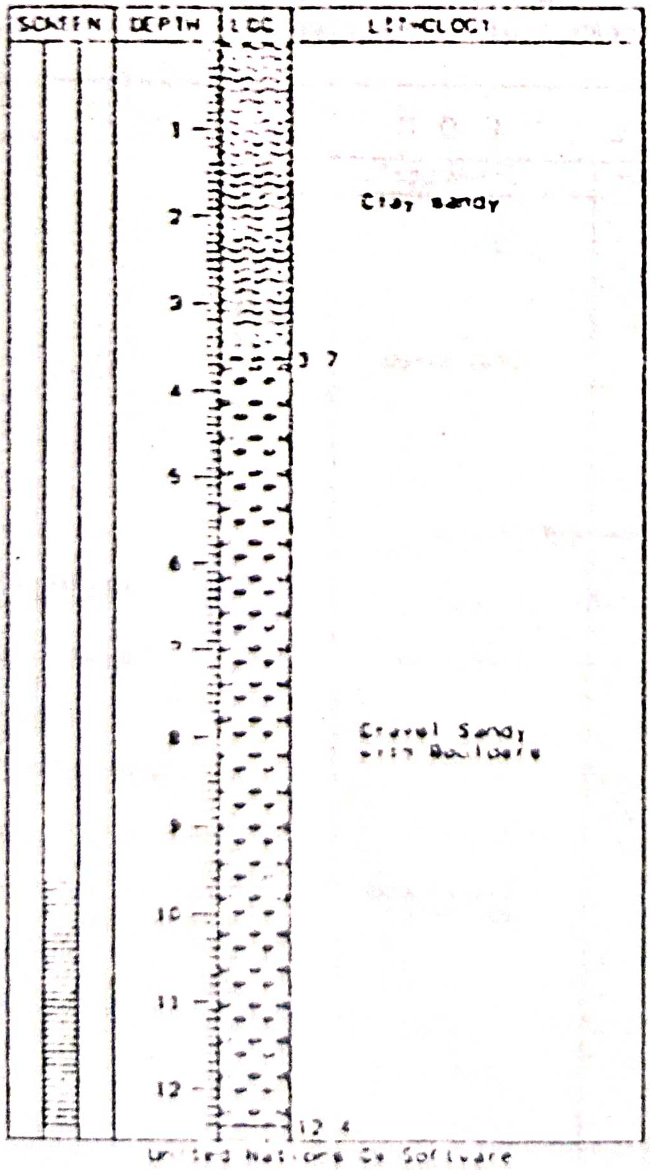
Capacity 12 l/s
SWL 9 75 m b.g.l.

Pump Test was not performed due to deep water level.

B 8. Log of UN 8

Well No UN 9	Location GODRANG
Elevation 173	X = 352000 Y = 306 [illegible]
Method of Drilling	MANUAL (Inchuwa), Boulders Zone
Drilling Dates	5 1 1991-7 1 1991
Total Depth	12 42
Comments	Well Size 4" M P 0 40 m Screen Position 9 67-12 42 Screen Type Perforated

WELL LOG

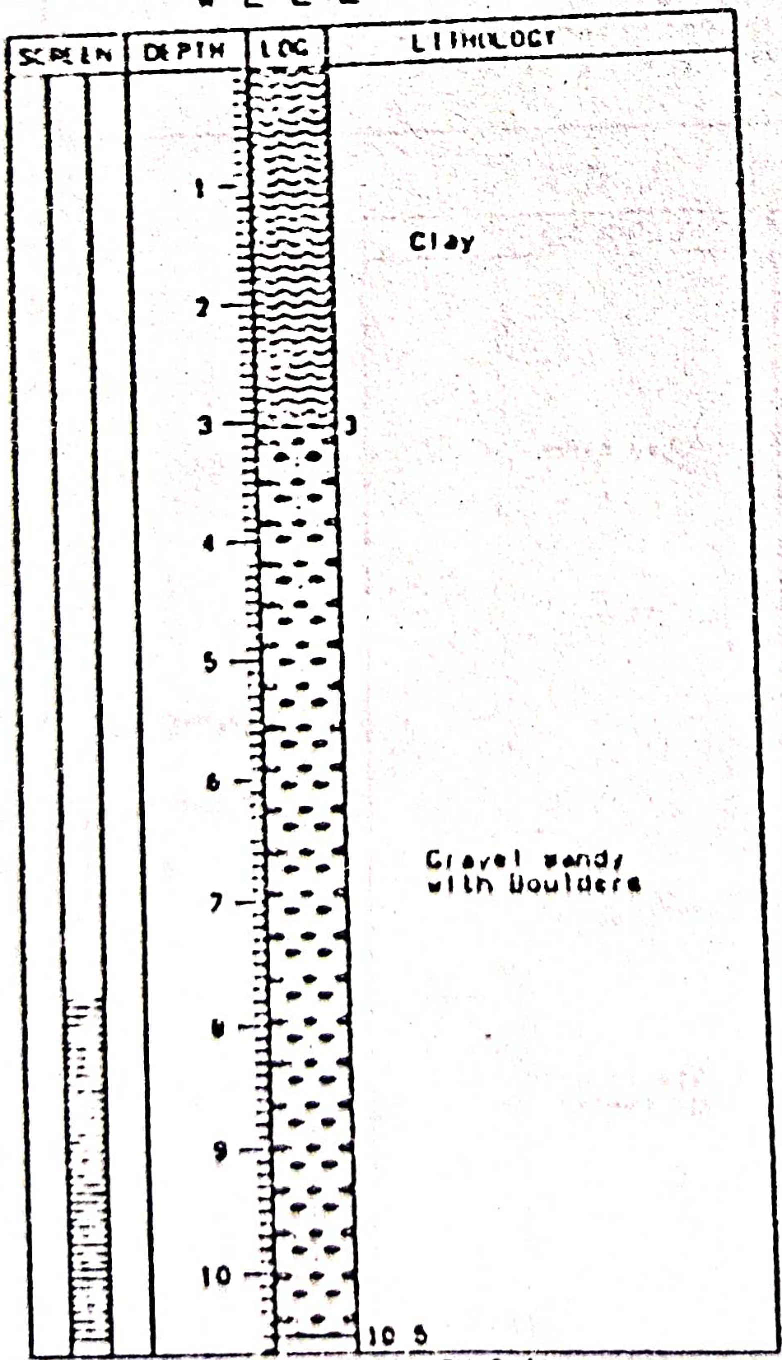


Not Tested

B 9. Log of UN 9

Well No UN 10	Location: TIKAULI
Elevation 185	X = 253500 Y = 3058000
Method of Drilling: MANUAL (Thokuwa), Boulders Zone.	
Drilling Dates 2 1 1991-3 1 1991	
Total Depth 10 50	
Comments: Well Size 4"Dia M P 0 50 m Screen Position 7 75-10 50 Screen Type Perforated	

WELL LOG



United Nations CV Software

PUMPING TEST

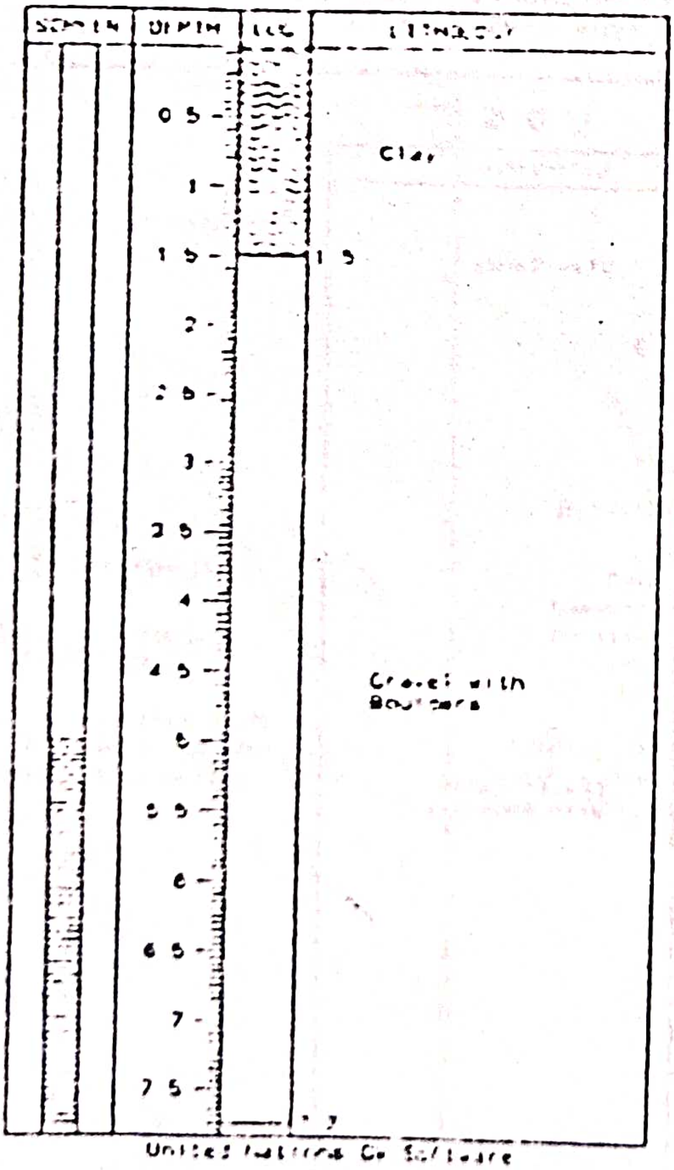
Date 3 3 1991
Capacity: 22 l/s
Duration: 180 Min
S.W.L. 2 60 m b g l.
D.W.L. 5 79 m b g l

Pumping Test was performed with Centrifugal Pump

B 10. Log of UN 10

Well No UN 11	Location RATAN NAGAR (Belchi)
Elevation 157	x = 256000 y = 3056500
Method of Drilling MANUAL(Thokuwa), Boulders Zone	
Drilling Dates 2 7 1991-4 7 1991	
Total Depth 7 75	
Comments Well Size 4"Dia M P 0 50m Screen Position 5-7 5 Screen Type Perforated	

W E L L   L O G



PUMPING TEST

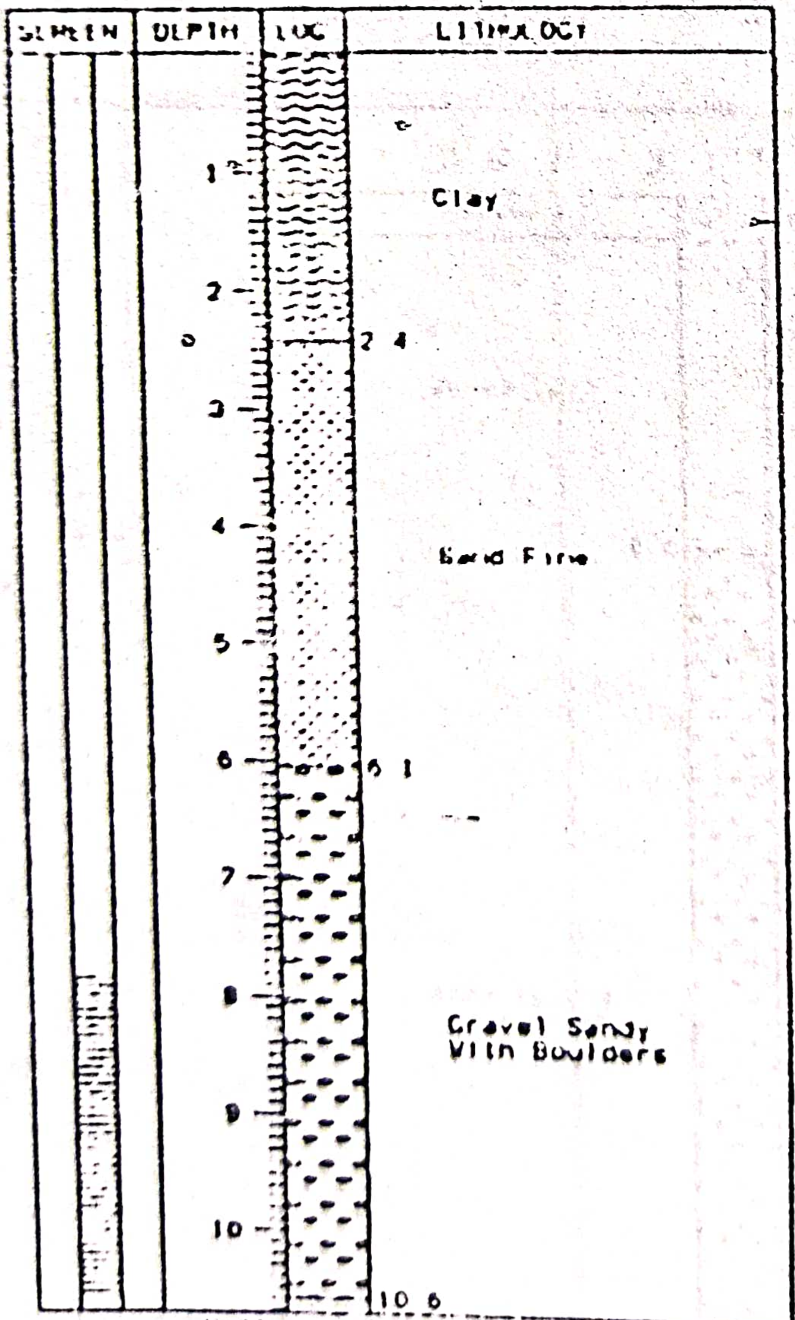
Capacity 22 l/s
SWL 0 92 m b g l

Not Tested

B 11. Log of UN 11

Well No UN 12	Location BARCHAULI
Elevation 152	x = 254500 y = 3053250
Method of Drilling	MANUAL(Thokuwa),Boulders Zone
Drilling Dates	23 1 1991-24 1 1991
Total Depth	10 60
Comments	Well Size 4"Dia M P 0 40 m Screen Position 7 85-10 56 Screen Type Perforated

WELL LOG



United Nations GW Software

PUMPING TEST

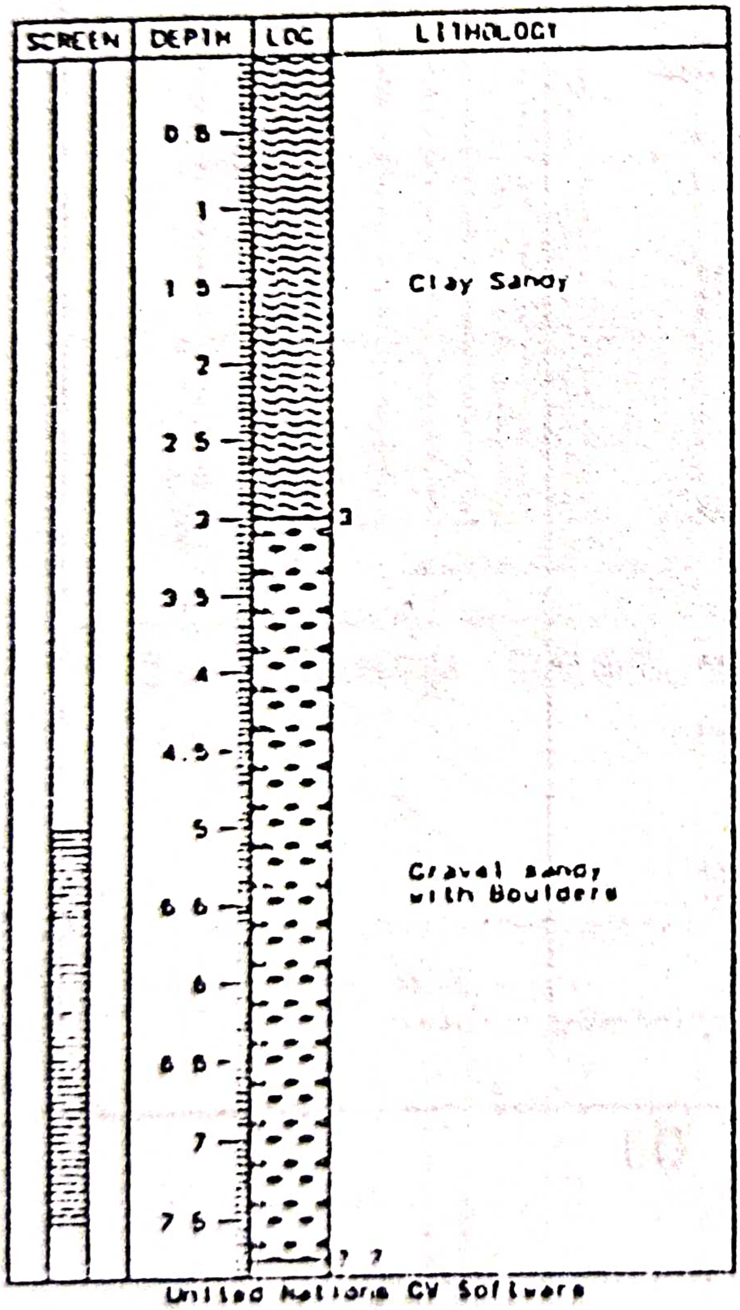
Date 27.2 1991
Capacity 22 l/s
Duration 80 Min
S.L. 2 72 m b g l
D.L. 5 16 m b g l

Pumpin Test was done with Centrifugal Pump

B 12. Log of UN 12

Well No UN 13	Location KHAIRAHANI
Elevation: 195 33	x = 259500 y = 3055750
Method of Drilling	MANUAL (THOKUVA), BOULDERS ZONE
Drilling Dates	29 7 1991-1 7 1991
Total Depth	7 75
Comments	Well Size 4" M P 0 50 m Screen Position 5-7 5 Screen Type Perforated

WELL LOG



PUMPING TEST

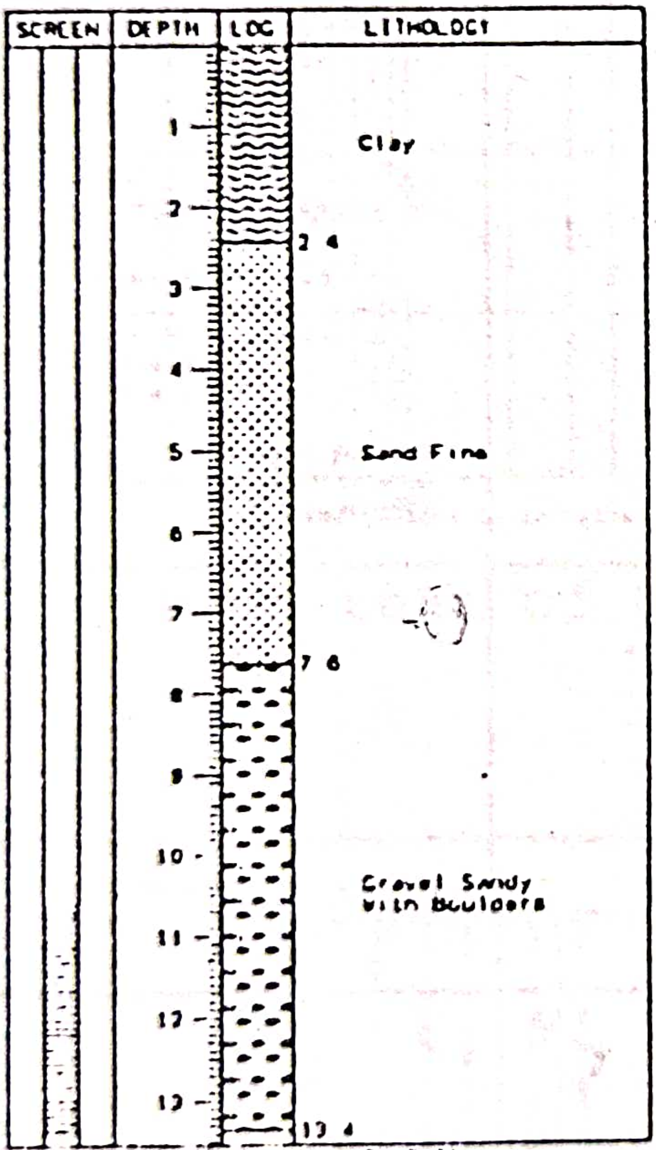
Capacity 20 l/s
SWL 2 17 m b g l
DWL 3 50 m b g l

Not Tested.

B13. Log of UN 13

Well No UN 14	Location KAPIYA
Elevation: 197 83	x = 261000 y = 3052500
Method of Drilling	MANUAL (Thokuwa), Boulders Zone
Drilling Dates	25 1 1991-26 1 1991
Total Depth	13 35
Comments	Well Size 4" Dia M P 0 40 m Screen Position 10 60-13 35 Screen Type Perforated

WELL LOG



United Nations Cv Software

PUMPING TEST

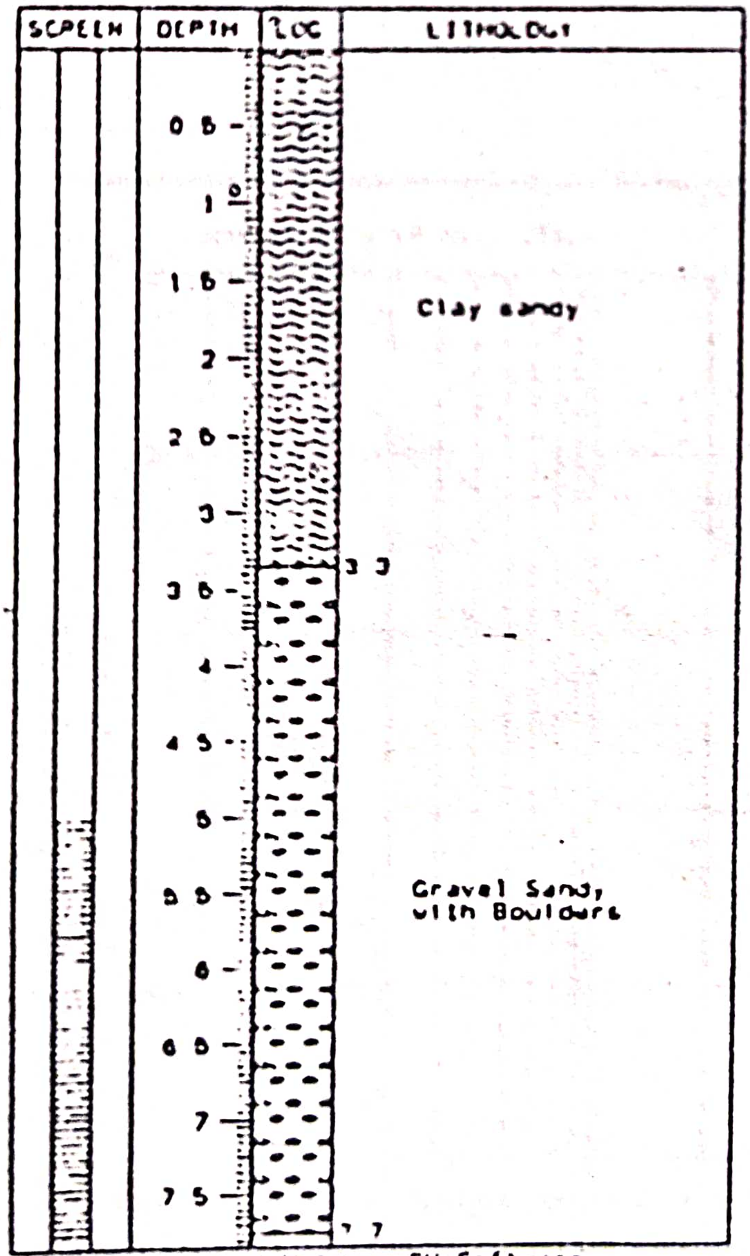
Date 5 3 1991
Capacity: 16 l/s
Duration: 300 Min
Transmiss. 766 m2/day
Method Jacob
SWL 2 79 m b g l
DWL 8 0 m b g l

Pumping Test was done with Centrifugal Pump

B 14. Log of UN 14

Well No UN 15	Location BIRENDRANAGAR
Elevation 209 41	x = 263000 y = 305
Method of Drilling	MANUAL (Thokuwa), Boulders Zone
Drilling Dates	26 7 1991-28 7 1991
Total Depth	7 75
Comments	Well Size 4"Dia M P 0 50 m Screen Position 5-7 75 Screen Type Perforated

W E L L L O G



United Nations GW Software

PUMPING TEST

Capacity 18 l/s

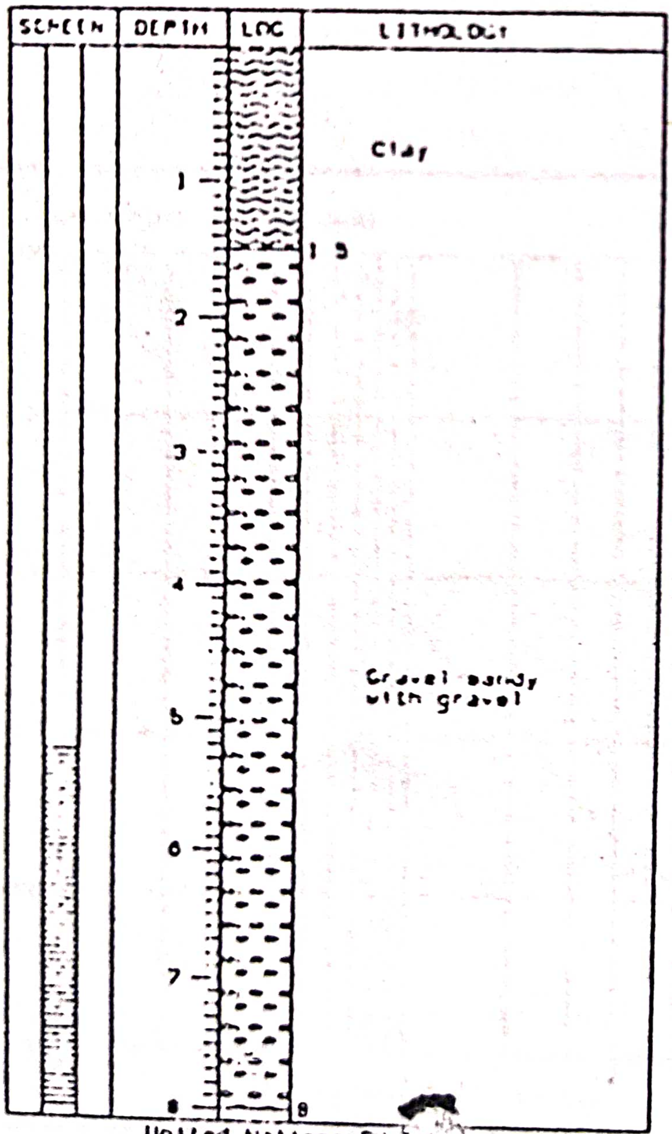
SWL 1 34 m b g l

Not Tested

B 15. Log of UN 15

Well No UN 16	Location BHANDARA (Parariya)
Elevation 216 80	x = 26 300 Y = 305 600
Method of Drilling	MANUAL (Thokuva), Boulders Zone
Drilling Dates	26 1 1991-28 1 1991
Total Depth	8 00
Comments	Well Size 4" Dia M.P.0 25 m Screen Position 5 25-8 Screen Type Perforated

WELL LOG



United Nations C[illegible]are

PUMPING TEST

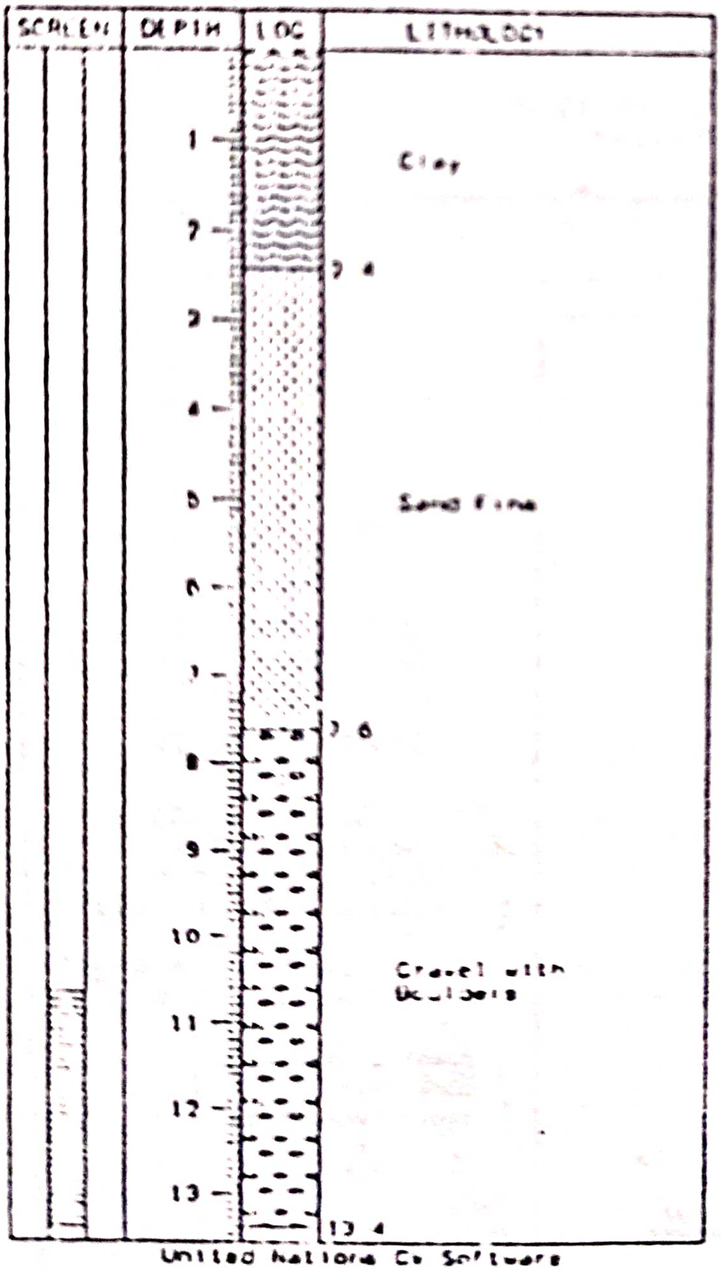
Capacity 5 l/s
SWL 3 6 m b g l

Not Tested

B 16. Log of UN 16

Well No UN 17	Location PIFLE (Pratap Pur)
Elevation 229 0	X = 271000 Y = 3253500
Method of Drilling	MANUAL (Thokuwa), Boulders Zone
Drilling Dates	2 2 1991 - : 2 1991
Total Depth	13 40
Comments	Well Size 4"dia M P 0 35 m Screen Position 10 65-13 40 Screen Type Perforated

WELL LOG



PUMPING TEST

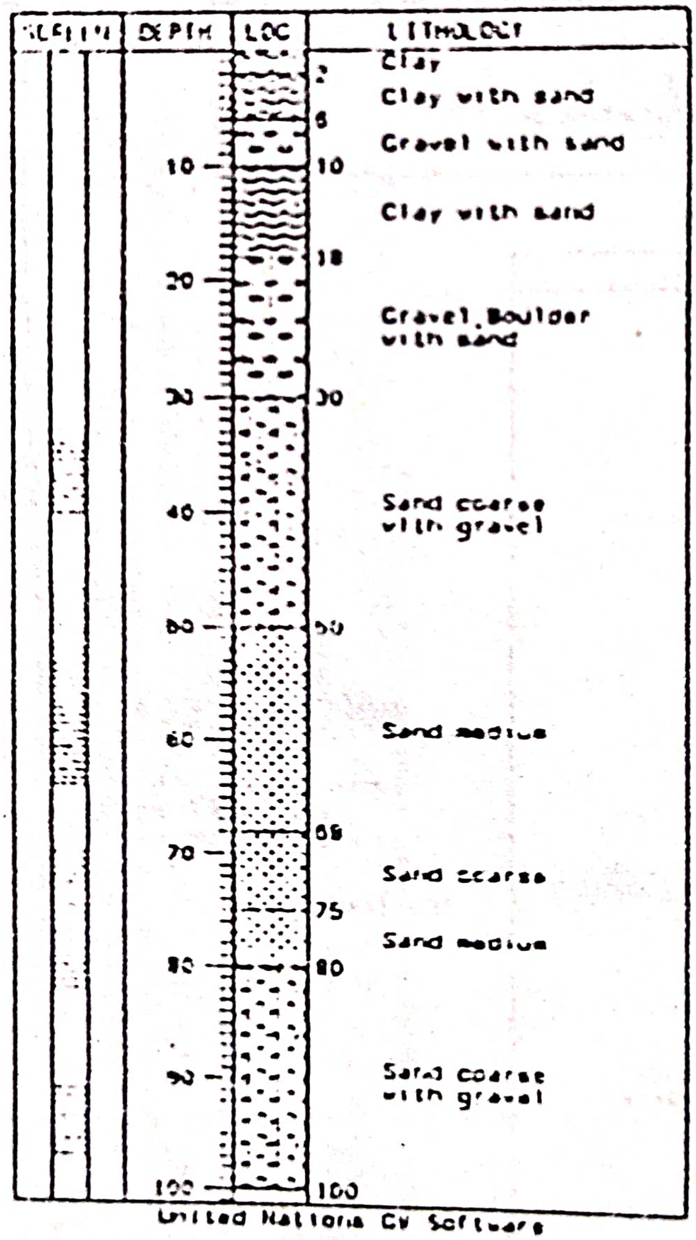
Date 14 3 1991
Capacity 2? l/s
Duration 120 Min
SWL 4 11 m b g l
DWL 4 95 m b g l

Pumping Test was done with Centrifugal Pump

B 17. Log of UN 17

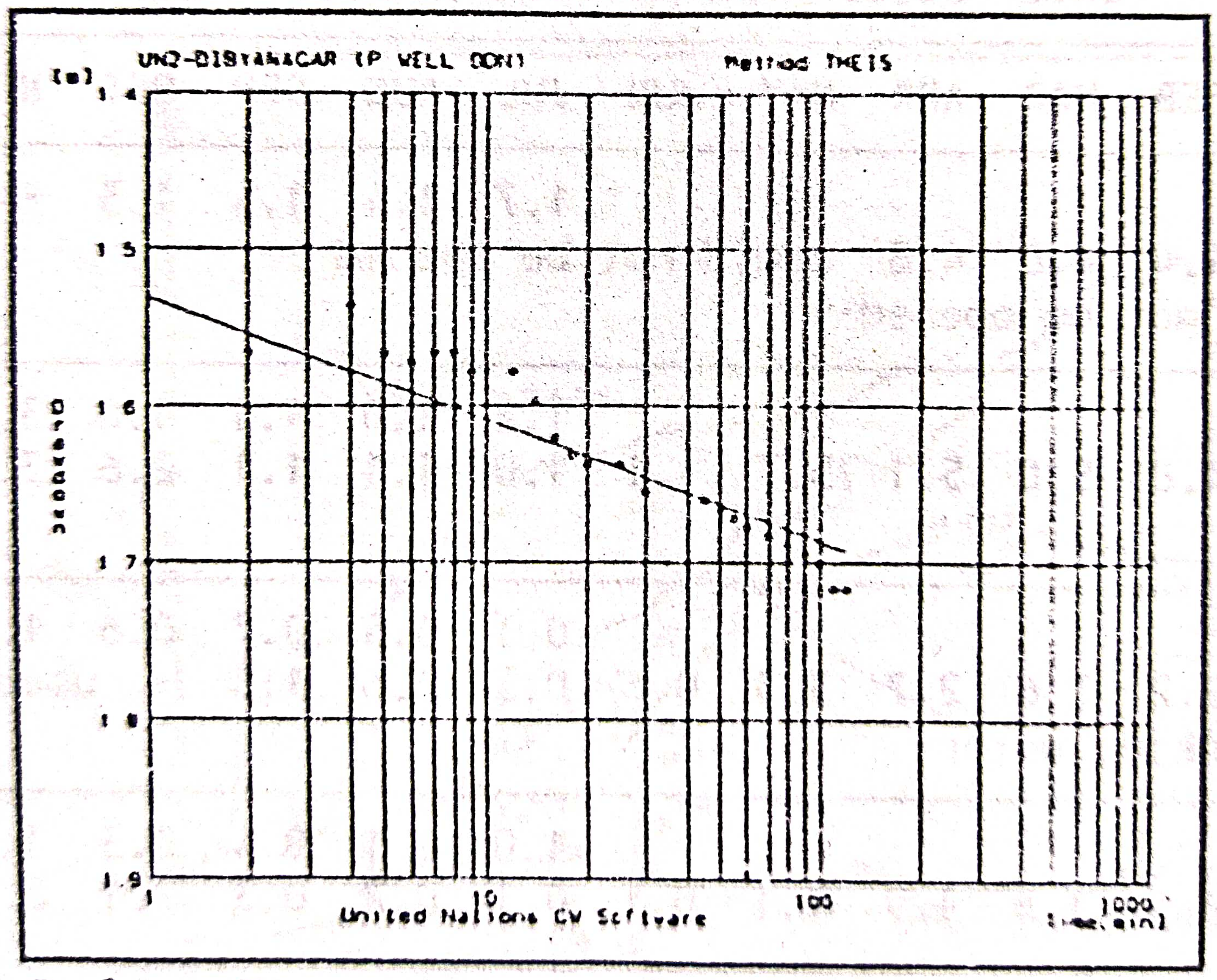
Well No NC 001	Location BHARATPUR
Elevation 200	x = 247200 y = 3065500
Method of Drilling	RIG
Drilling Dates	28 11 86 - 14 14 87
Total Depth	100 00
Comments	Well size 10/6" Screen position 34 - 40, 64 - 70 m 70 - 82, 91 - 97 m Screen type Slotted

WELL LOG

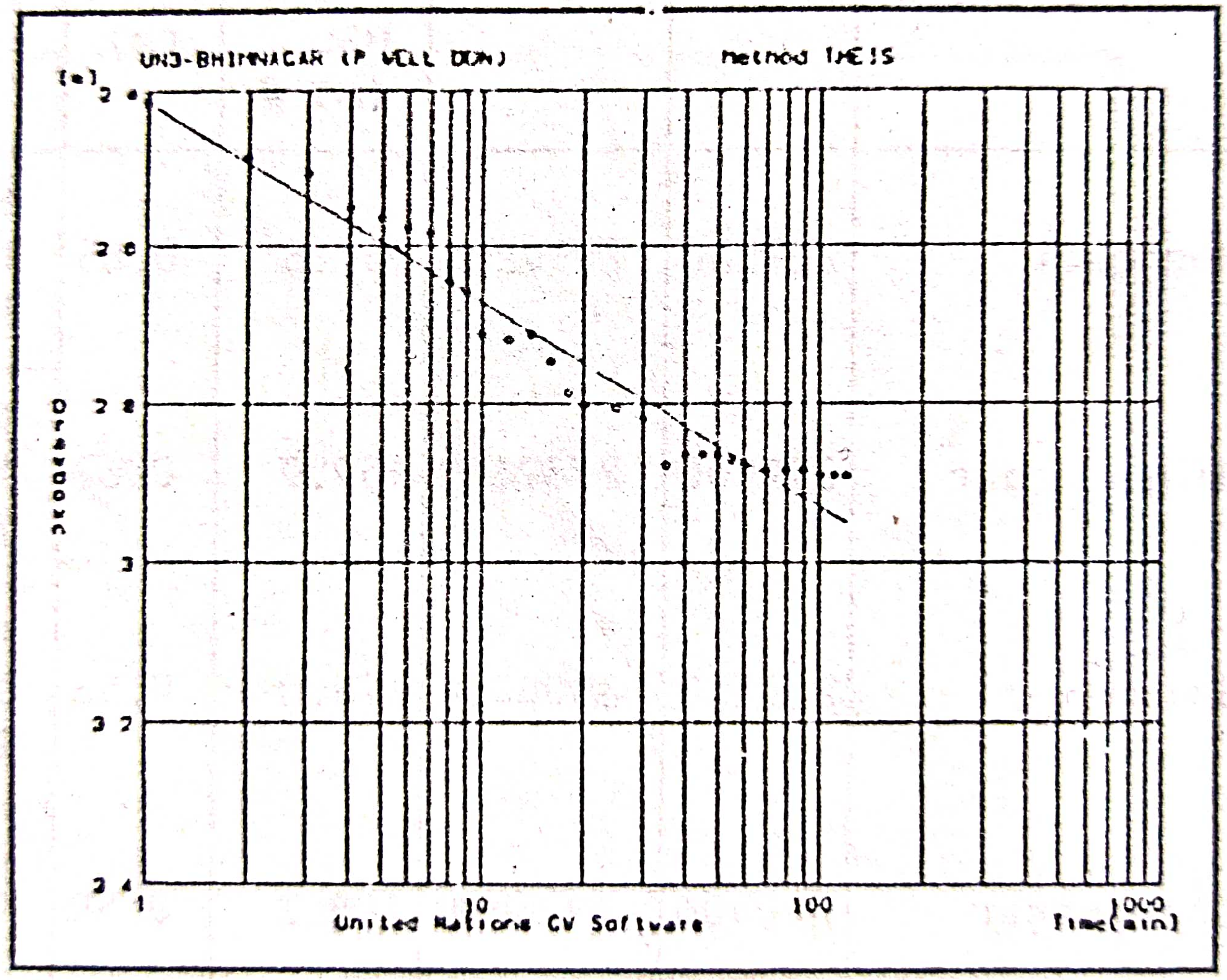


United Nations GW Software

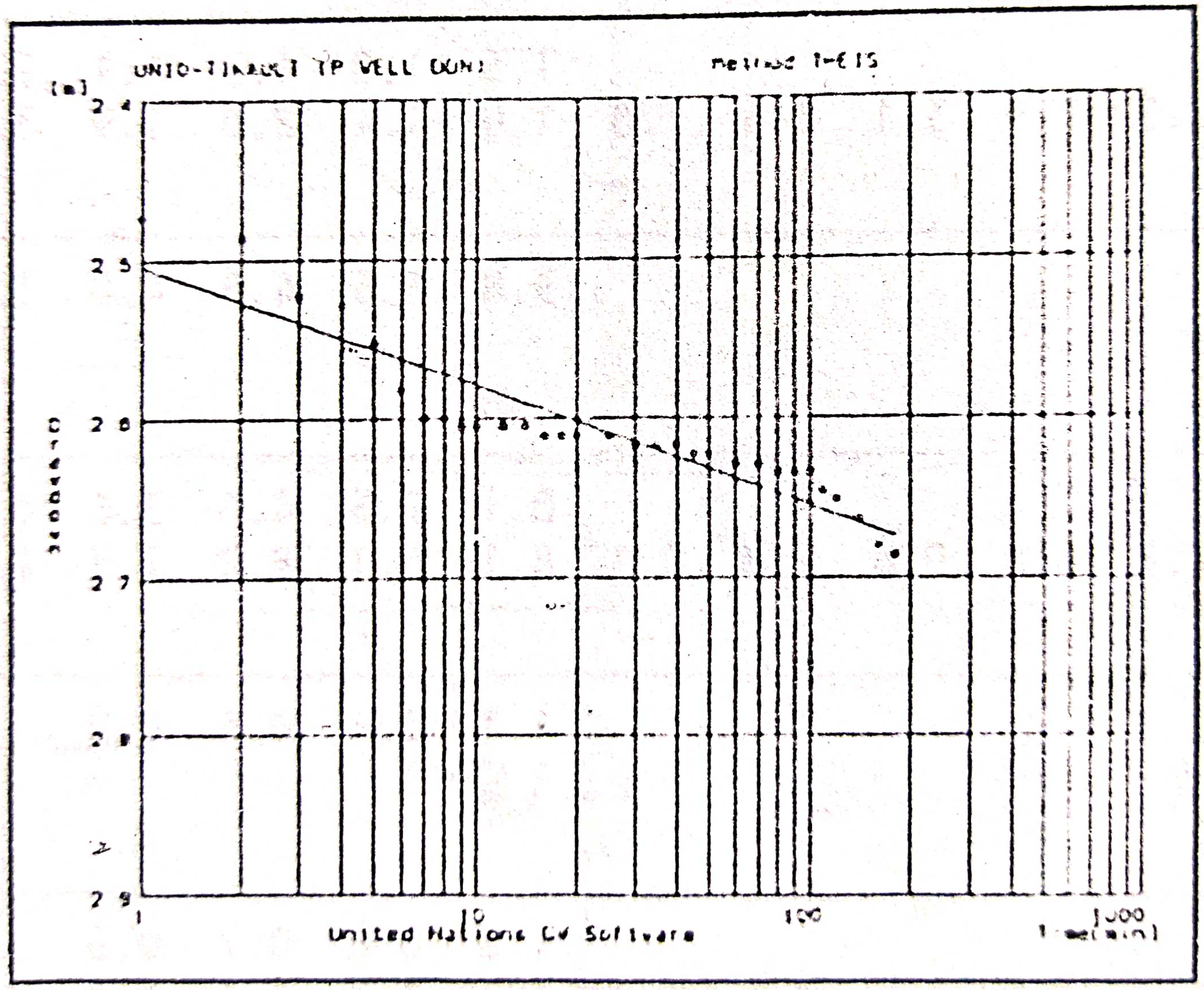
B 18. Log of NCD 01



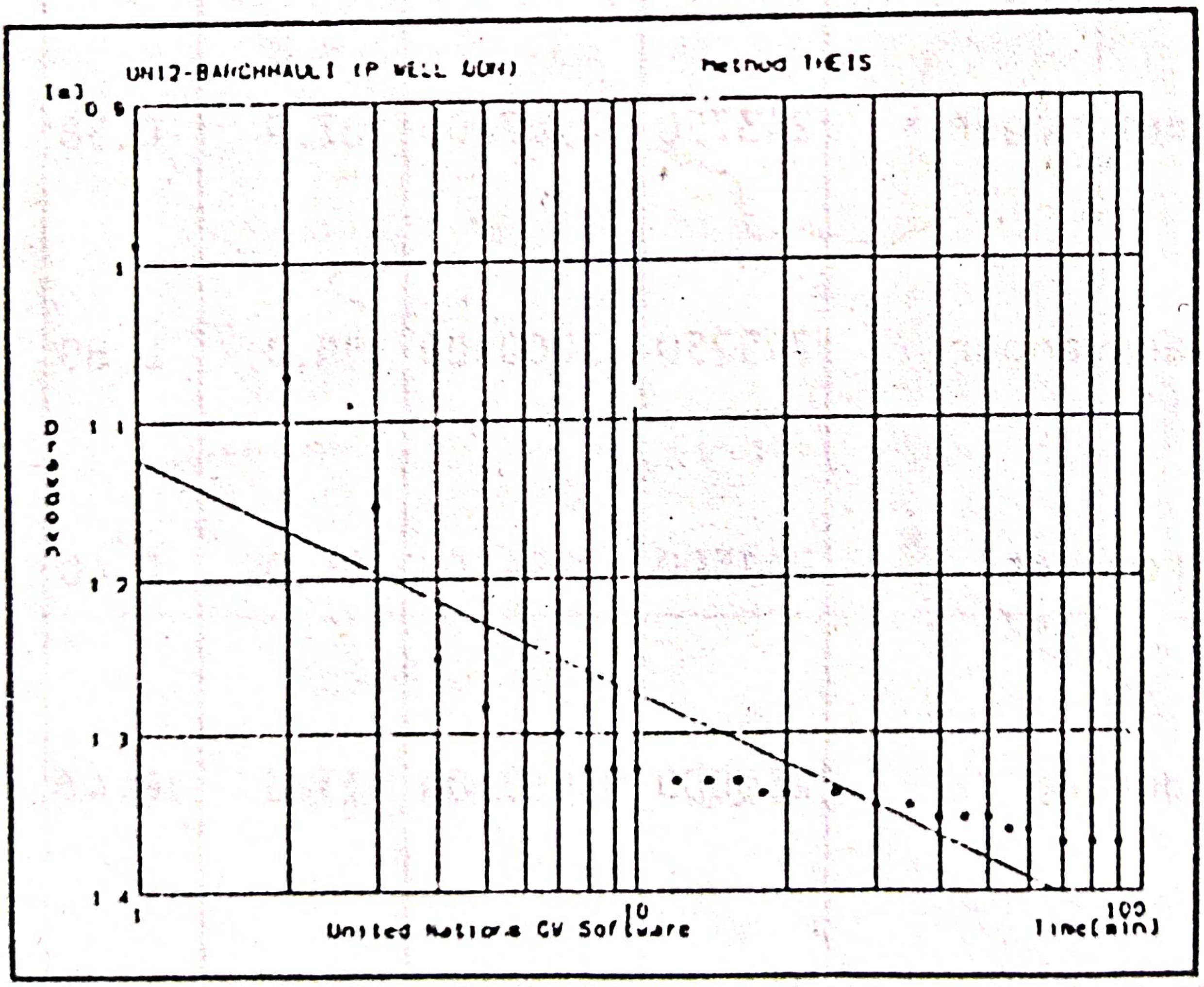
C-1.   Pump test of Un 02 by Theis



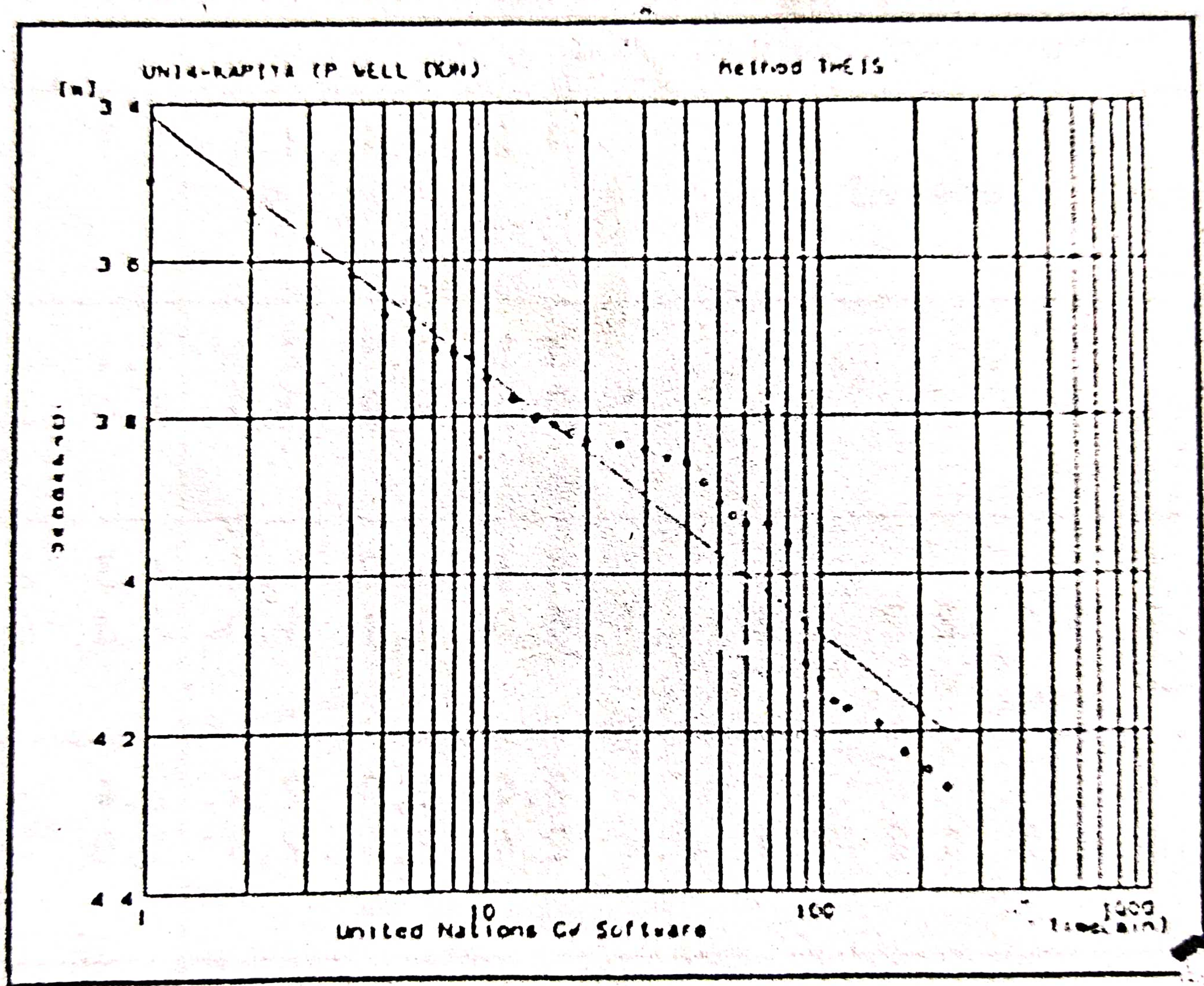
C-2. Pump test of UN 03 by Theis



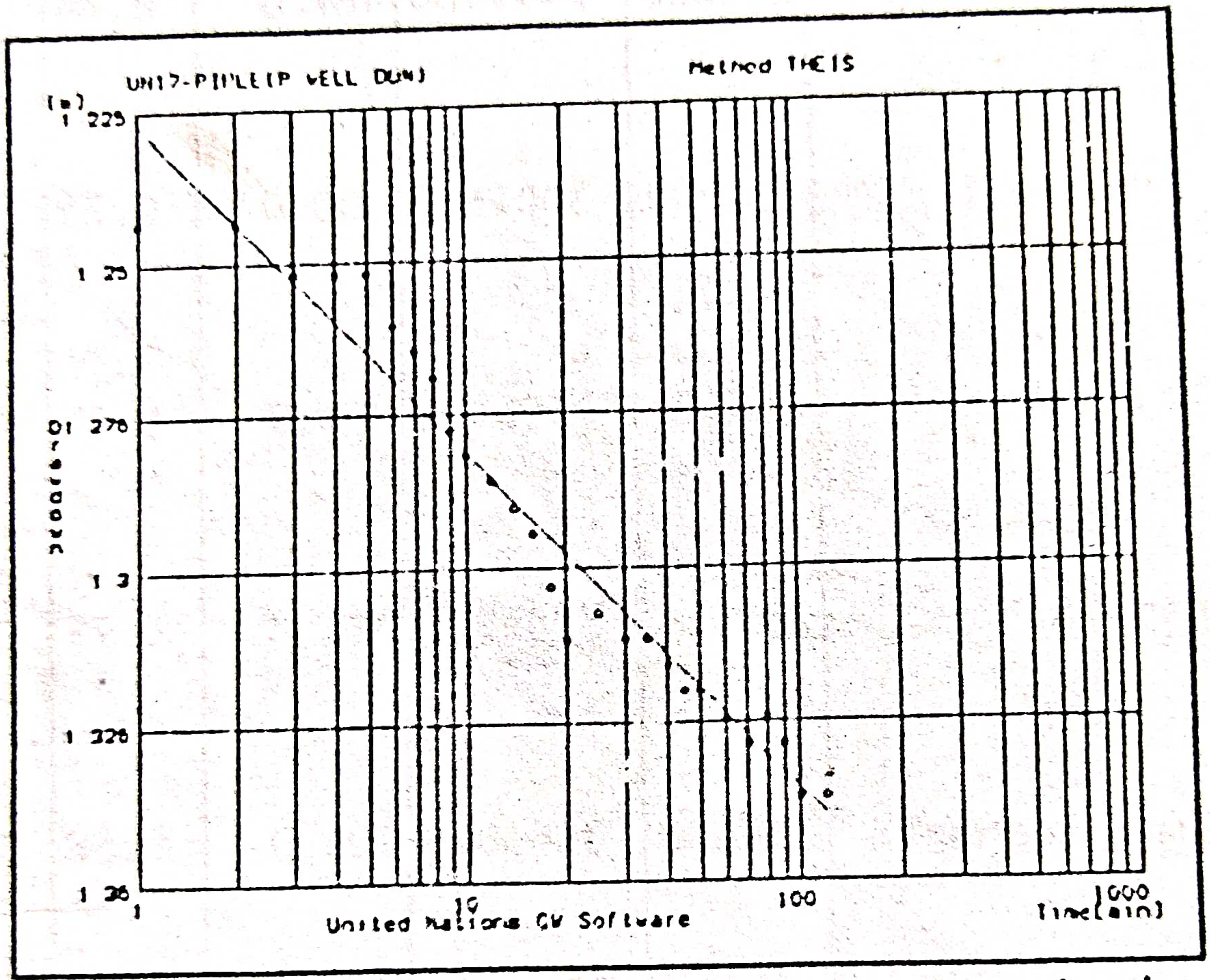
C-3. Pump test of UN 10 by Theis



C-4. Pump test of UN 12 by Theis



C-5. Pump test of UN 14 by Theis

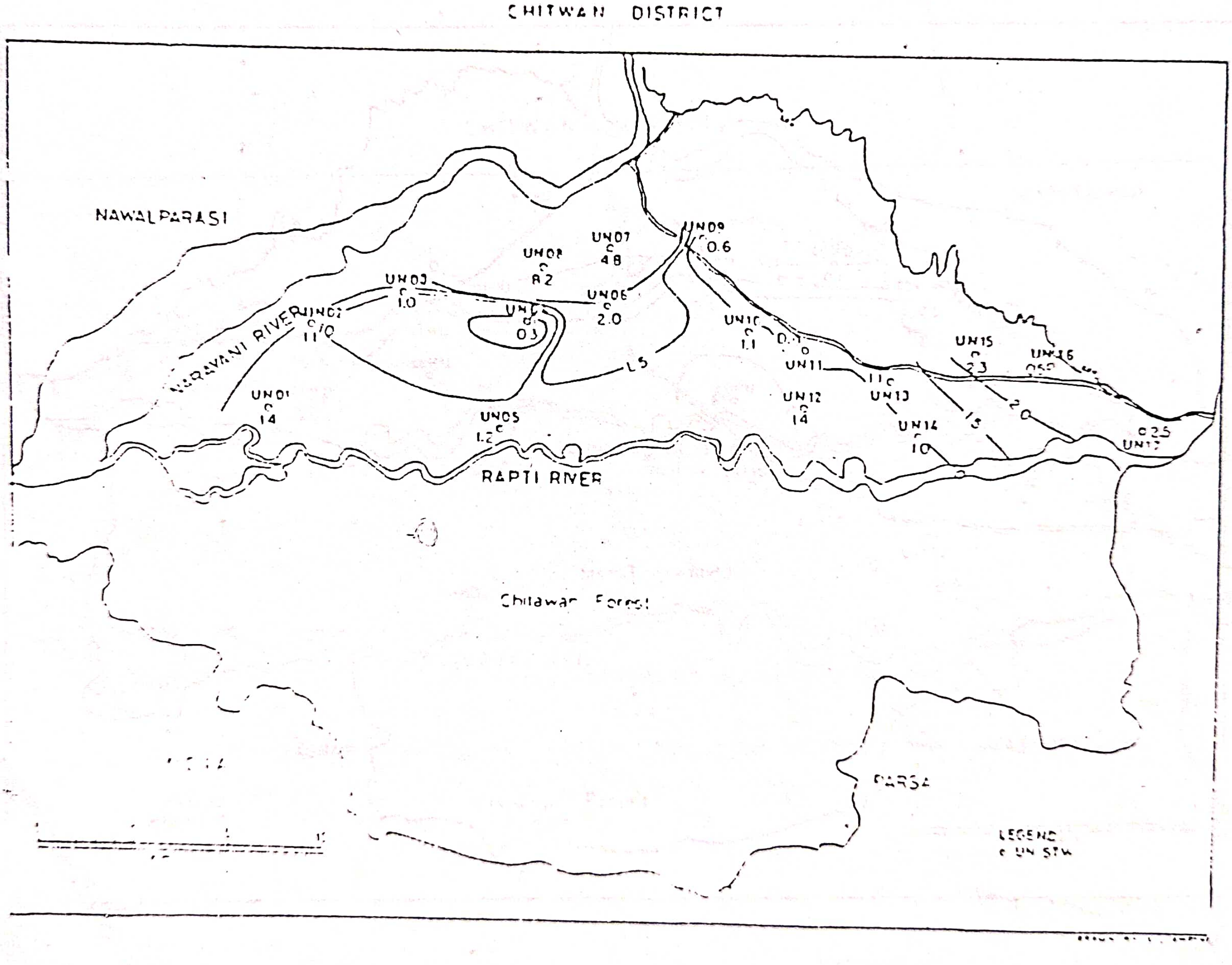


C-6. Pump test of UN 17 by Theis

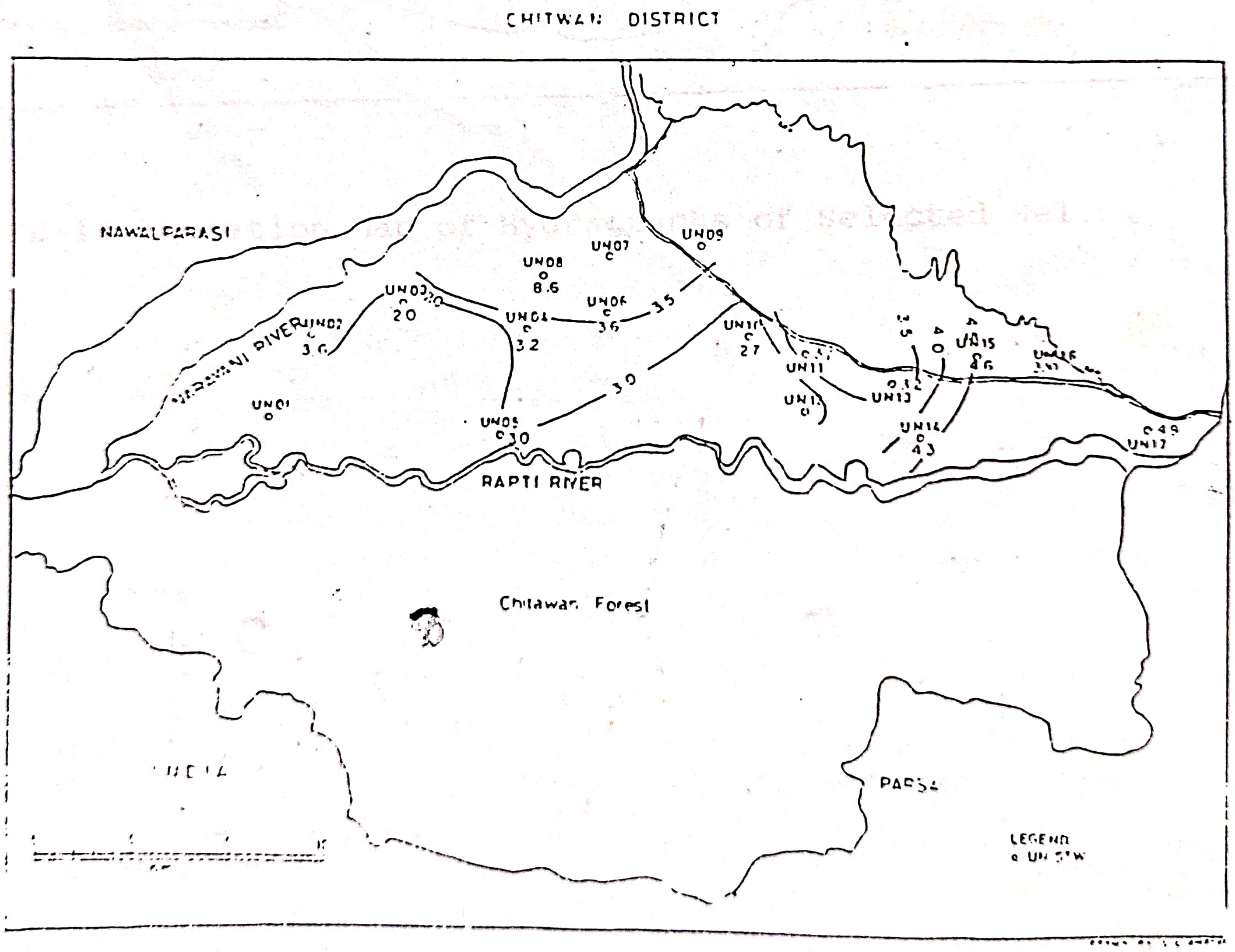
D-1: Monthly Water Level Measurement Data in Project STWs in Chitwan District

Well No.	Village Name	X	Y	Elev. MSL (m) #	M.P. (m)	Year	Water Level Measurements in meters (BGL) JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
UN 01	Meghauli	227250	2999200	150.6	0.85	1991							1.7	1.4	1.4	1.3	-	-
						1992	4.2	4.4	4.6	4.8	could not be opened --							
						1993	could not be opened--											
UN 02	Dibya Nagar	229500	2989800	159.9	0.62	1991							1.2	1.0	1.1	1.0	3.6	4.3
						1992	4.5	4.8	5.0	5.1	5.7	1.1	1.0	1.1	1.1	2.6	3.2	3.6
						1993	4.1											
UN 03	Bhimnagar	234250	3000000	175.0	0.56	1991							0.1	0.5	0.7	0.6	1.7	2.0
						1992	2.1	2.2	2.6	2.7	3.3	0.6	0.5	0.6	1.0	-	used for	-
						1993	- drinking water-											
UN 04	Shivanagar	240500	2995000	188.2	0.50	1991							1.0	0.1	0.4	0.3	1.7	1.2
						1992	1.4	1.5	1.8	1.9	3.1	0.1	0.1	0.2	0.3	2.1	2.7	3.2
						1993	3.9											
UN 05	Pathihani	239250	2998000	178.3	0.64	1991							1.4	0.9	1.1	1.0	2.6	2.0
						1992	2.2	2.6	2.7	2.8	2.6	1.0	1.0	1.1	1.2	1.9	2.9	3.0
						1993	3.8											
UN 06	Geetanagar	243750	2987200	187.9	0.58	1991							1.5	1.0	1.3	1.1	2.6	2.3
						1992	2.4	2.5	2.9	3.1	3.3	1.0	1.0	1.4	2.0	1.9	3.6	3.6
						1993	3.9											
UN 07	Narayanpur	245250	3000500	188.0	0.80	1991							3.8	8.5	4.8	4.0	3.3	Fille
						1992	Filled											
						1993	,,											
UN 08	Prembasti	241500	2994700	184.0	0.40	1991							8.1	7.5	4.6	3.6	6.2	6.9
						1992	7.7	7.8	8.0	9.6	2.8	8.1	8.1	8.1	8.2	7.3	8.1	8.6
						1993	9.3											
UN 09	Godrang	250000	3063000	193.0	0.43	1991							1.1	0.6	0.6	0.2	1.0	Fille
						1992	Filled											
						1993	,,											
UN 10	Tikauli	253500	2992200	185.0	0.37	1991							1.0	0.6	0.7	0.6	2.2	2.3
						1992	2.4	2.6	2.8	1.6	1.5	1.3	1.3	1.3	1.1	1.6	2.1	2.7
						1993	3.0											
UN 11	Ratan Nagar.	256000	2999900	187.0	0.78	1991							0.7	0.4	1.5	1.2	2.8	-
						1992	2.0	2.4	2.7	2.9	2.5	1.1	1.0	1.1	0.9	2.5	3.6	3.6
						1993	4.0											
UN 12	Barchauli	254500	3004600	188.0	0.76	1991							1.2	0.4	1.4	1.1	2.6	-
						1992	could not be opened											
						1993	,,											
UN 13	Khairahani	259500	2995400	195.3	0.55	1991							1.5	1.3	2.6	1.1	2.7	2.8
						1992	2.8	3.2	3.3	2.9	2.6	2.1	2.1	2.2	1.1	2.4	3.0	3.2
						1993	3.7											
UN 14	Kapila	261000	3004500	197.8	0.75	1991							1.3	0.8	1.6	1.3	2.6	2.[illegible]
						1992	2.6	2.9	3.0	2.2	2.6	1.3	1.0	1.1	1.0	2.3	4.1	4.3
						1993	4.4											
UN 15	Birendranagar	263000	3056000	205.0	0.58	1991							2.4	2.0	2.4	2.4	-	-
						1992	4.4	4.6	4.7	4.5	4.1	2.4	2.4	2.4	2.3	3.0	4.4	4.6
						1993	5.5											
UN 16	Bhandara	268000	3056000	216.8	0.87	1991							0.8	0.7	1.7	0.2	2.9	3.[illegible]
						1992	2.1	2.2	2.4	1.1	2.8	0.5	0.5	0.5	0.5	1.9	3.0	3.[illegible]
						1993	3.6											
UN 17	Piple	271000	3005800	229.0	0.35	1991							2.9	2.7	4.2	4.5	-	-
						1992	4.6	4.8	4.9	2.9	2.6	2.7	2.6	2.6	2.5	3.6	4.4	4.[illegible]
						1993	5.2											

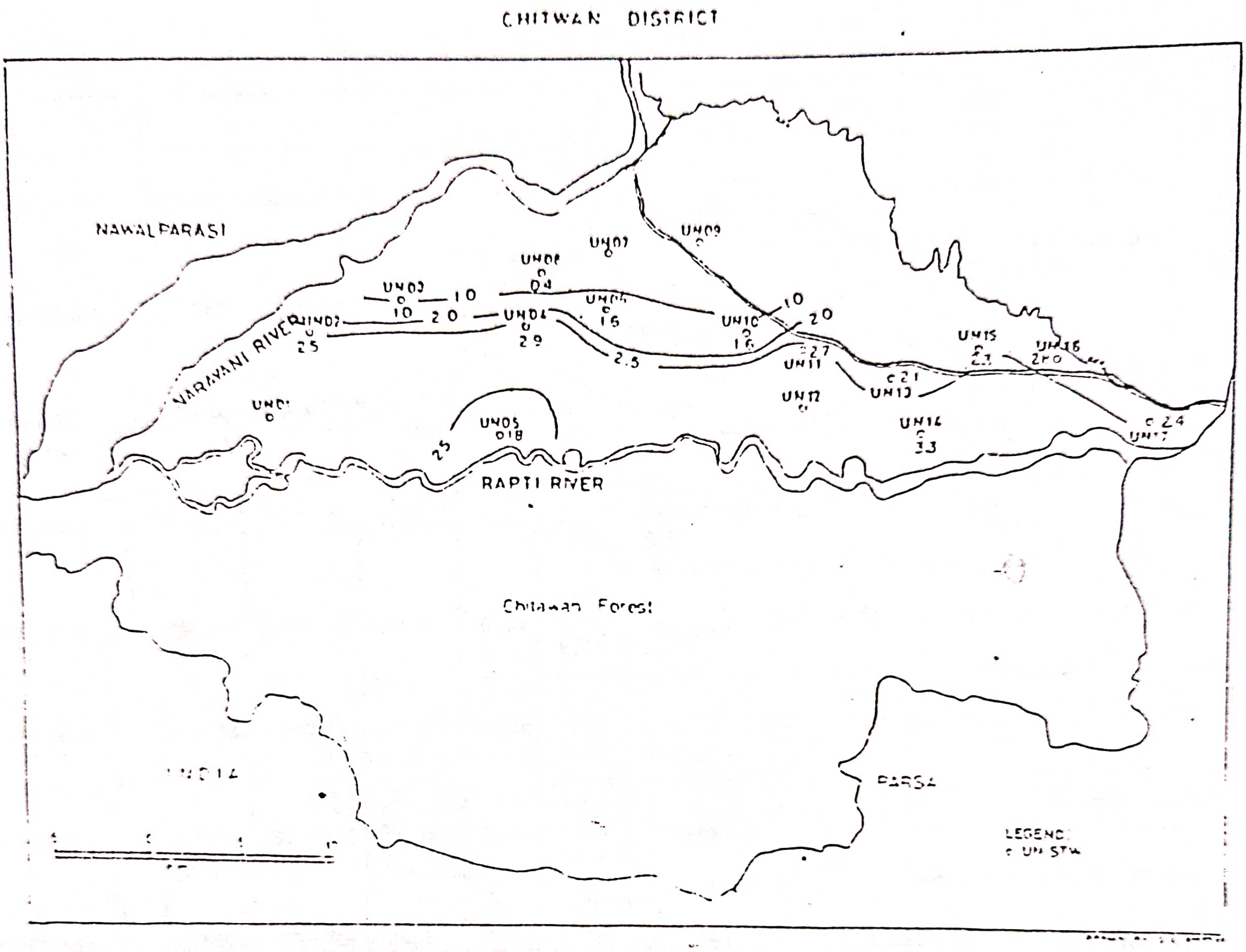
D-2. Water Level Fluctuation Maps in 1992



D-2/1. Depth to Water Table in September 1992



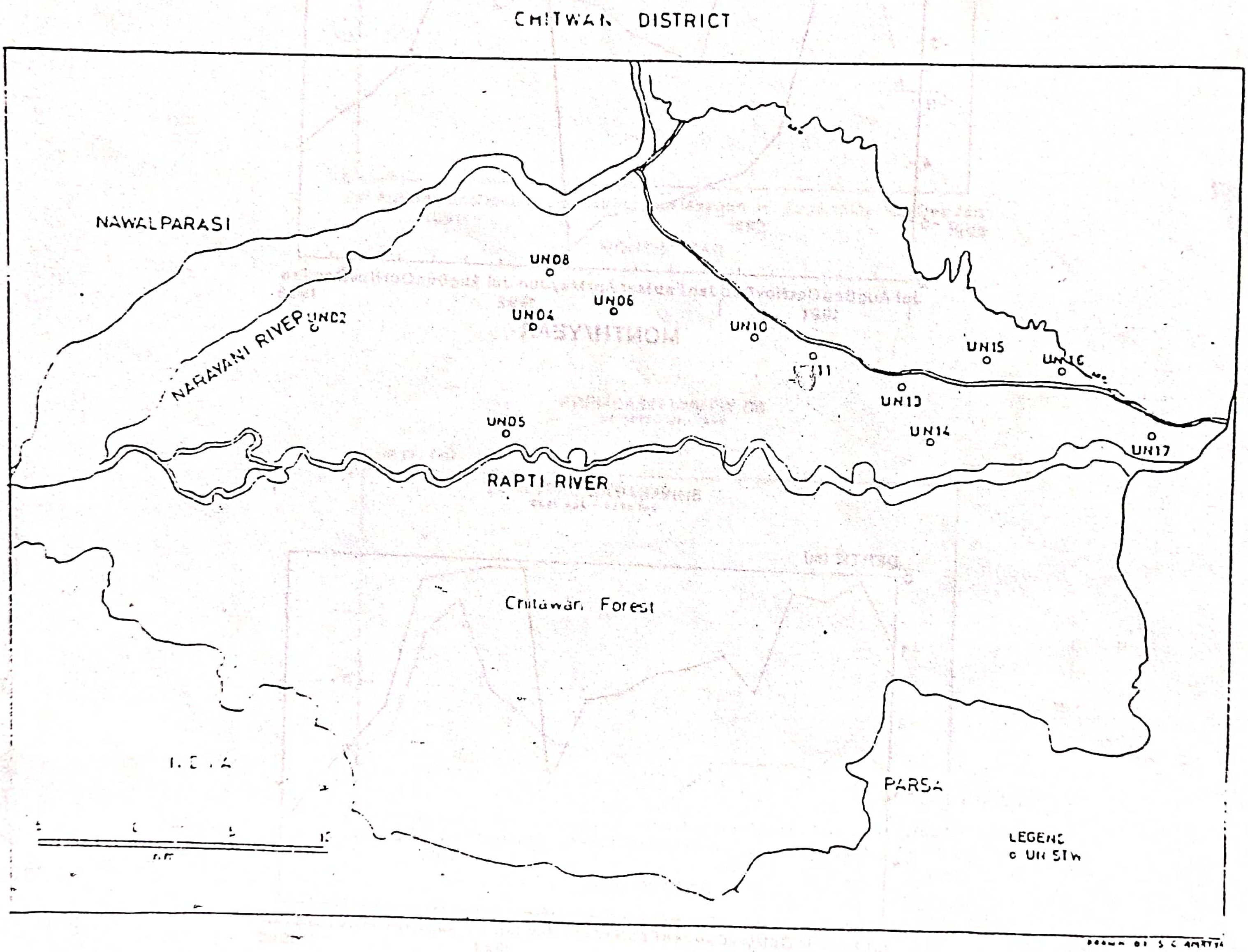
D-2/2. Depth to Water Table in December 1992



D-2/3. Rise of Water Table in Sept.-Dec. 1992

APPENDIX E

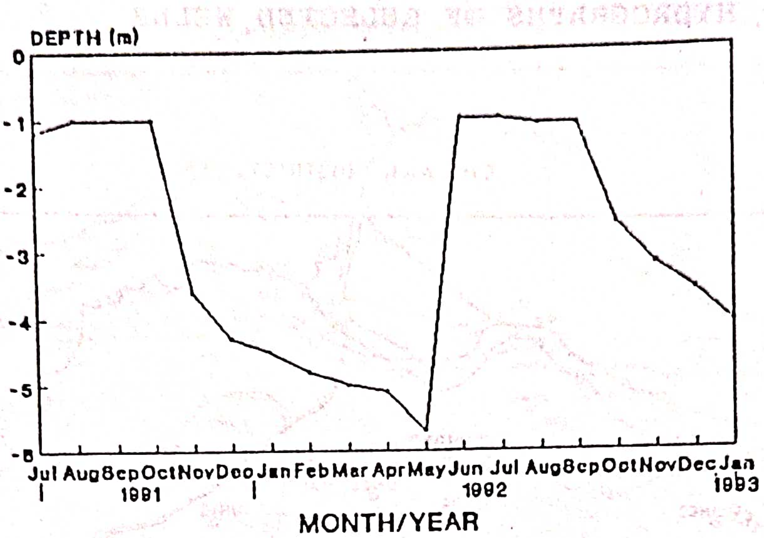
HYDROGRAPHS OF SELECTED WELLS



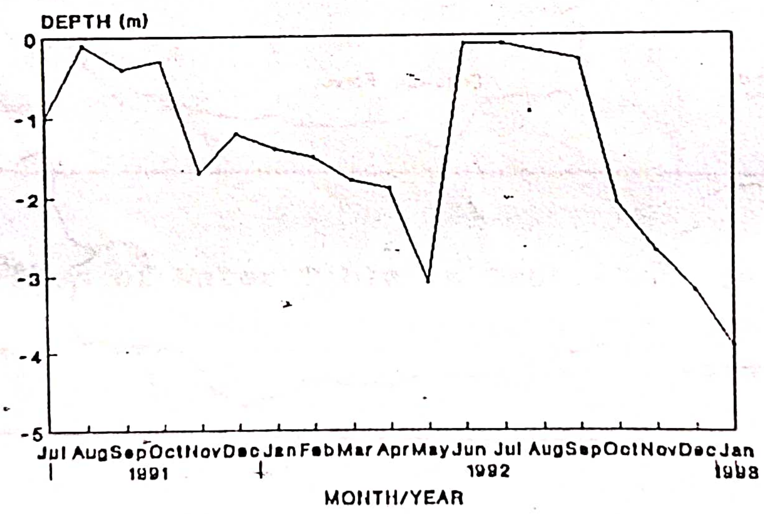
E-1. Location Map of Hydragraphs of Selected Wells

HYDROGRAPHS

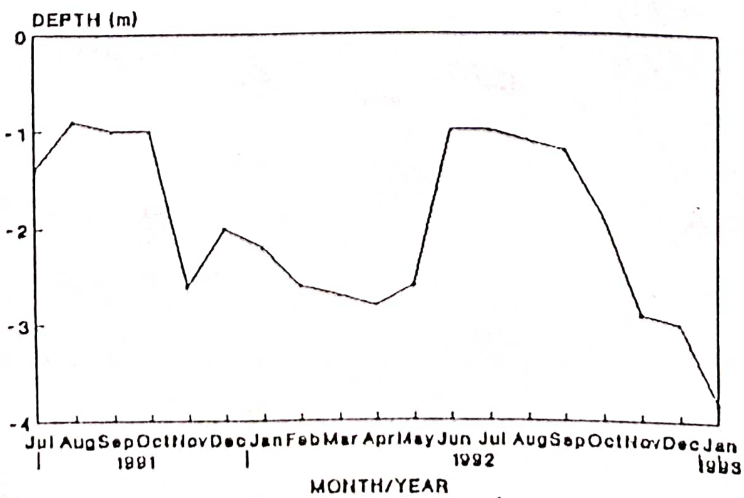
DIBYANAGAR - UNSTW 02
Jul 1991 - Jan 1993



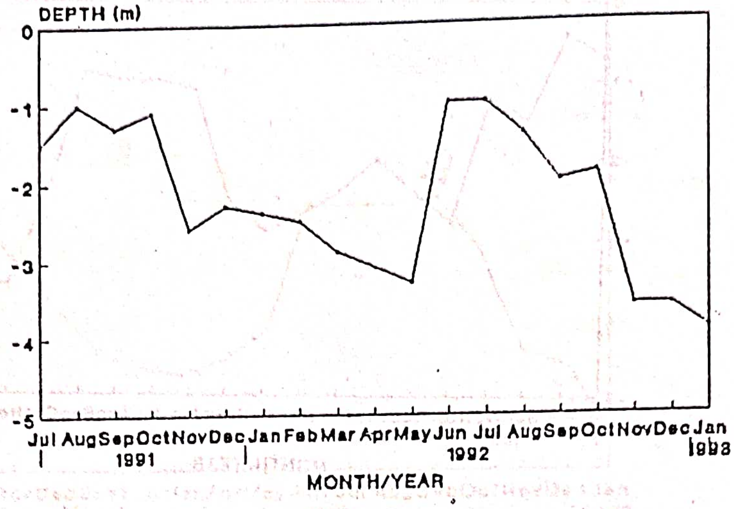
SHIVANAGAR UNSTW 04
Jul 1991 - Jan 1993



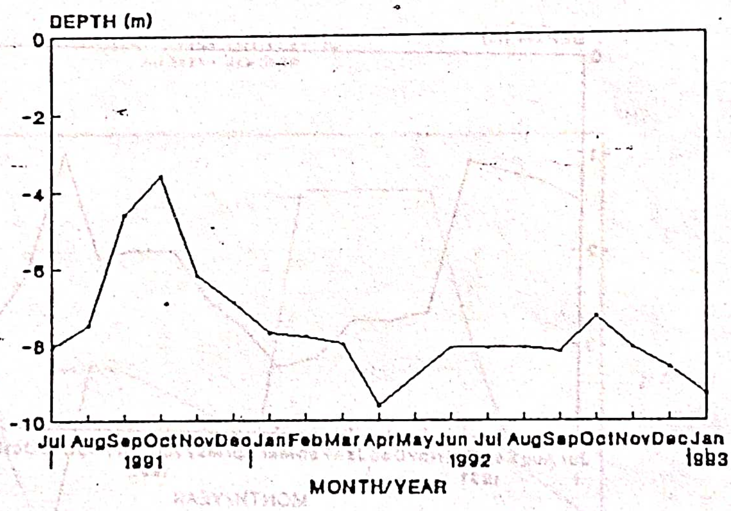
PATHIHANI UNSTW 05
Jul 1991 - Jan 1993



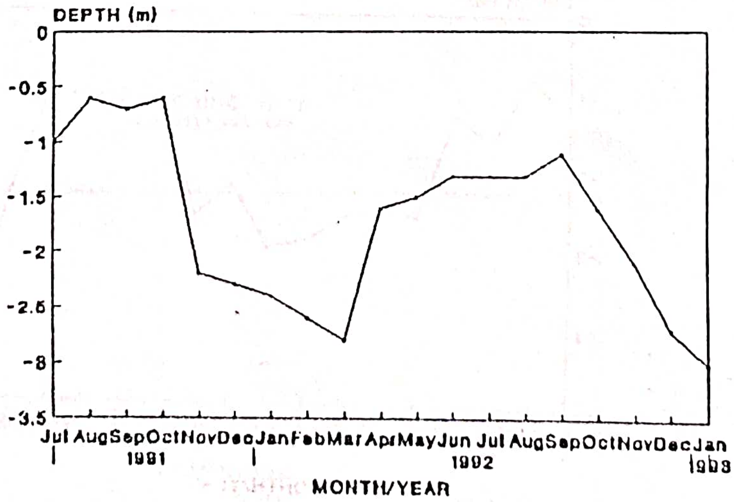
GEETANAGAR UNSTW 06
Jul 1991 - Jan 1993



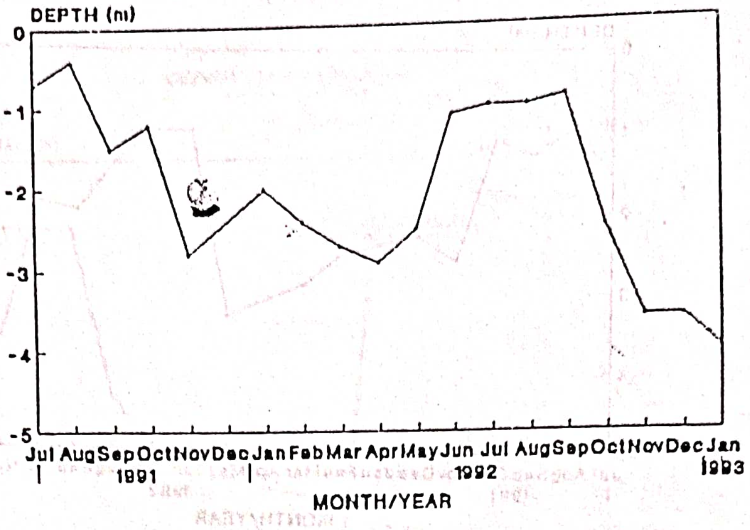
PREMBASTI UNSTW 08
Jul 1991 - Jan 1993



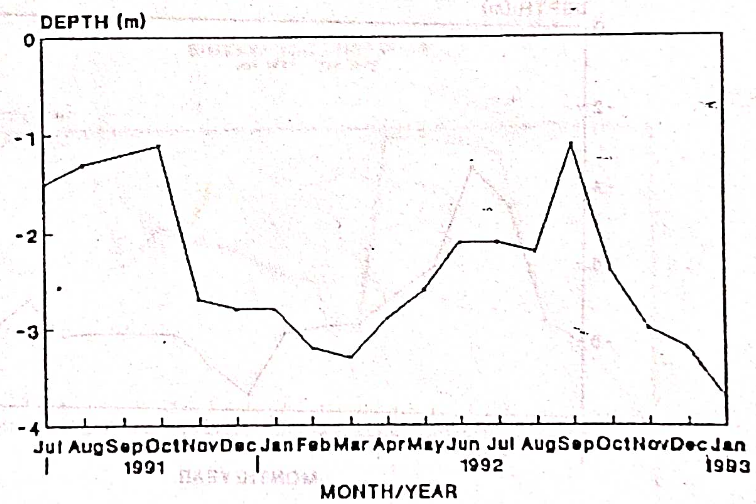
TIKAULI UNSTW 10
Jul 1991 - Jan 1993



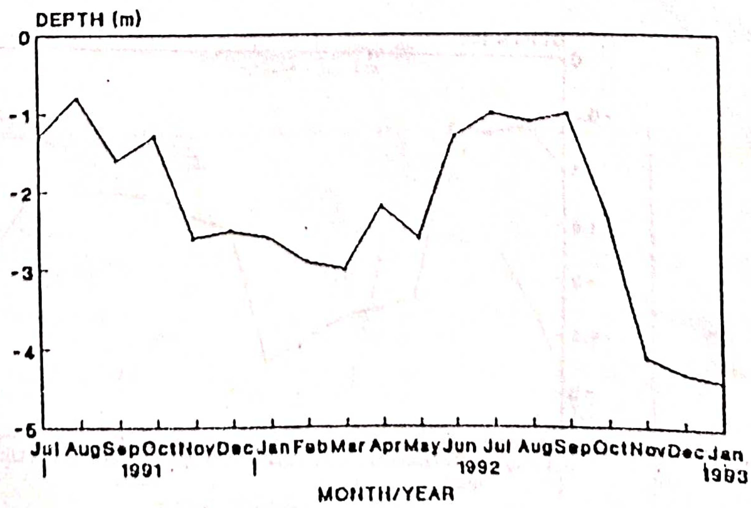
RATAN NAGAR UN11
Jul 1991 - Jan 1993



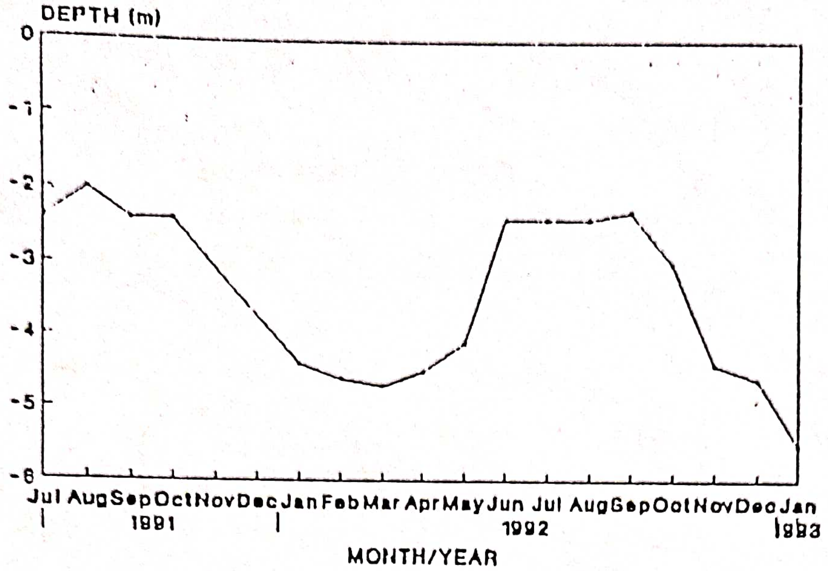
KHAIRAHANI UN13
Jul 1991 - Jan 1993



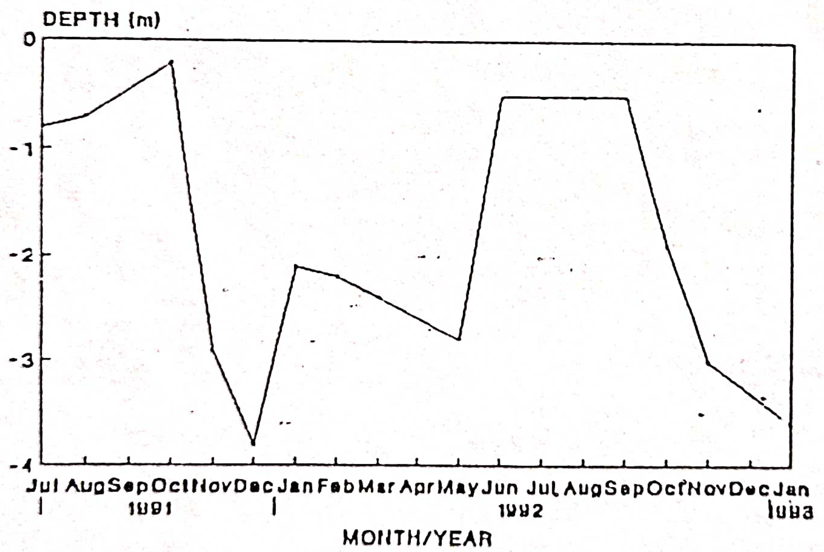
KAPILA UN14
Jul 1991 - Jan 1993



BIRENDRANAGAR UNSTW 15
Jul 1991 - Jan 1993



BHANDARA UNSTW 16
Jul 1991 - Jan 1993



PIPLE UNSTW 17
Jul 1991 - Jan 1993