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

Technical Report No. 27

By

RAMESH M. TULADHAR, Senior Divisional Geologist, GWRDB
with assistance of
ECHHYA K. SHRESTHA, Geohydrologist, GWRDB

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

NEP/86/025
Shallow Ground Water Investigations in the Terai
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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
NRCS	-	National Remote Sensing Center, Nepal/GTZ/World Bank
STW	-	Shallow Tube Well
UNDP	-	United Nations Development Programme
UN/DTCD	-	United Nations Development of Technical co-operation for Development

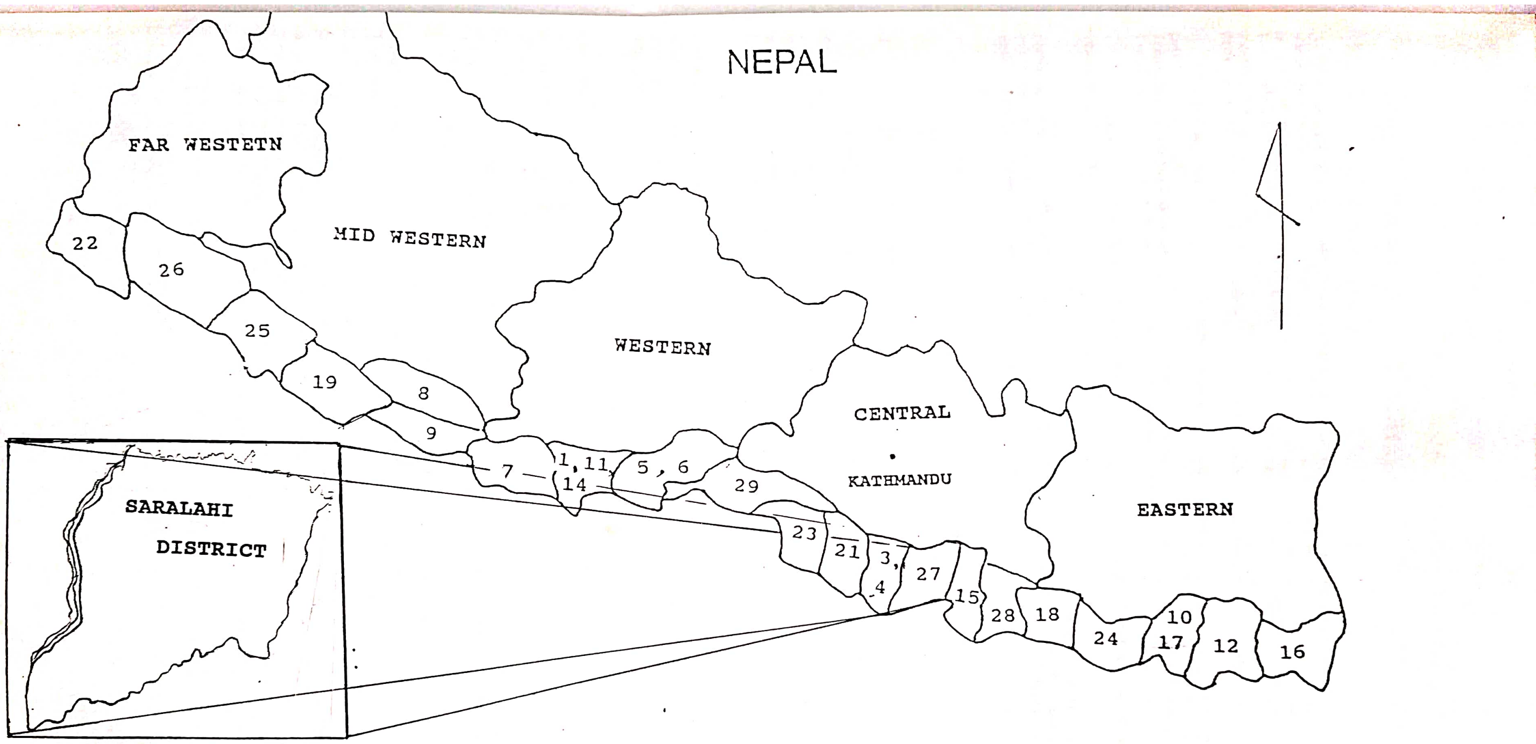

Figure 1. Index Map Showing Technical Reports No. from the Ground Investigations in the Terai

ABSTRACT

Sarlahi District, which comprises an area of 1259 Km2 in Central Development Region of Nepal, is about 84% in the Terai and about 16% in the Siwalik Hills Physiographic province. The average annual precipitation is about 1650 millimeters of which more than 81% comes during the monsoon. Agriculture is the dominant economic activity in the district. Approximately 25% of the farm land is irrigated for a single crop and about 29% for more than a single crop. The aquifers in Sarlahi have the potential to provide water to irrigate the remaining 71% of unirrigated or single crop irrigated land.

The aquifer is an indeterminate number of interconnected lenses of permeable sand, gravel and pebbles intercalated with some silts and clays which comprise a very large ground water reservoir. Transmissivities, as determined from 20 pumping tests, range from less than 40 to almost 12700 m2/day. Yields of wells range from 1 to 25 liters per second (l/s).

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

Recharge in the district is principally from local precipitation. Estimates of potential recharge vary from about 158 MCM to more than 305 MCM per year. This compares favorably with the estimated ground water outflow to India of 8.8 MCM per year and a hypothetical pumpage of 156 MCM per year calculated from 2000 wells pumping 10 l/s for six hours each day.

1. INTRODUCTION

1.1 Purpose and Scope

The United Nations Department of Technical Co-operation for Development and the Ground Water Resources Development Board, 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 Sarlahi 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 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 Sarlahi District 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

Sarlahi District is the third district from east in the Central Development Region of Nepal. It lies between the LANDSAT IMAGERY (NRSC, 1987) co-ordinates: X x333000 - 378000 and Y = 2959000 - 3003000. Sarlahi District borders on the west with Rauthat District along the Bagmati River and Mahhotari District on the east along the Banke Khola in upper part and the Hardi Khola in the lower part respectively. It has India to its south and the Sindhuli District to the north. Malangawa is the administrative headquarter of this district, and is connected by a seasonal road with the national East-West Highway. The total area of Sarlahi District is about 1259 km^2 (Statistical Year Book of Nepal, 1991), and is largely covered by the Terai (northern part of Indo-gangaitic Plain) portion which is considered to be about 1240 km^2 (Tillson,1985). However, from the 1: 125000 district map published by the Department of Survey (1986) the Siwalliks Hills (arbitarily above 250 m contour) covers about 200 km2 that leaves 1059 km2 area for the Terai. This portion is discussed in this report. Unlike in most other districts the whole map (Figure 1) inculding Siwaliks is presented in all the figures used in this report.

1.3 Previous Investigations

Sarlahi 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 and completed in the spring of 1990. The work consisted of drilling wells, making water level measurements, lithologic determinations and aquifer tests. Altitude surveys of land surfaces at wells were carried out in 1991 (DEVTEC Nepal,1991).

The current project had a target of drilling 900 total meterage with 20 wells of each 31.4 m depth in average. However, a total of only 627.44 m in 20 wells were drilled between May and April 1990. The new wells were located to obtain maximum geographic coverage within the Terai and thus maximum information about the nature of the aquifer. Manual methods were used to drill 11 of the 20 wells and 9 were drilled with a rotary rig. Drill cuttings were collected and examined. Lithologic logs and other information were collected on 20 project drilled wells, and one deep tube well drilled by GWRDB.

Water level monitoring in Sarlahi District was initiated in May 1987 with an ambitious monitoring network that included 40 dug wells. But for various reasons, regular monthly water level measurements in those wells are not available. It is only since April 1990 that a regular water level measurement data from a monitoring network consisting mostly of the Project (Nep/86/025) drilled wells became available.

Aquifer or pumping tests were conducted on all 20 project wells and five observation wells (private wells drilled under the program of Agricultural Development Bank, Nepal) were also pump tested. However, these tests were marginally performed.

The drilling metrage, number of project wells and pumping tests in Sarlahi are shown in Figures 2 and 3 respectively.

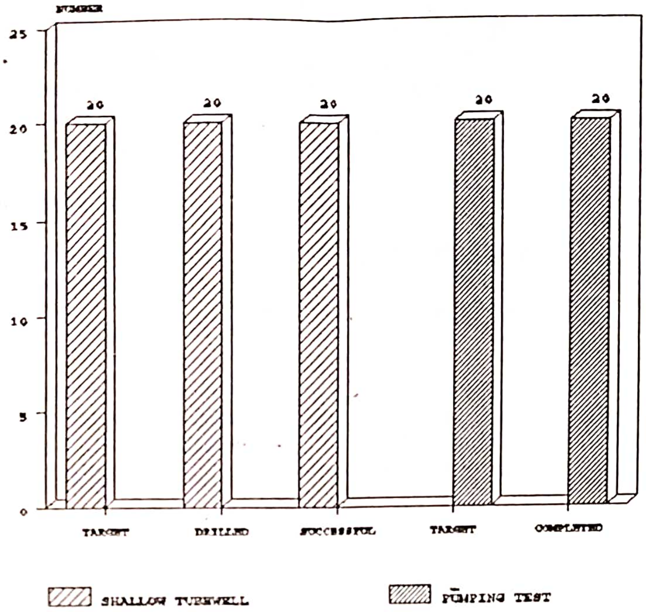

Figure 2: Number of wells and pumping tests in Sarlahi District

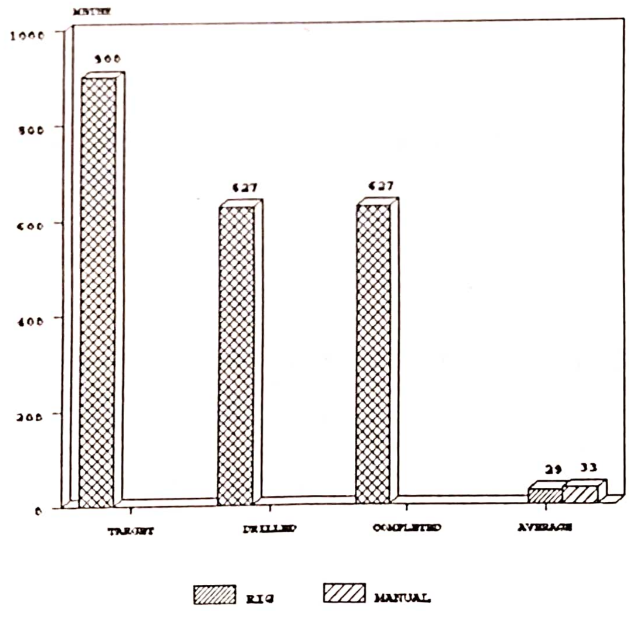

Figure 3: Drilling meterage in Sarlahi District.

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 SL for Sarlahi 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 wells drilled for GWRDB (DTW 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

Sarlahi District is in the Terai Physiographic Province of Nepal in the south and in the Siwalik Hills Province in the north. Altitudes in Sarlahi District range from more than 600 meters in the north to more than 70 meters at the border with India.

The Bagmati river is the biggest river in the district, which forms the western border with Rauthat District of Central Development Region. Several other streams, such as Lakhandehi Khola, Jhim Nadi, Banke Khola etc. are the other streams in the district. All of these streams flow from north to the south.

1.7 Climate

The climate of Sarlahi District is subtropical with a mean monthly temperature of 15° C in January and 31° in June. High humidity is prevalent except in winter and becomes oppressive in summer. The climatic characteristics of Sarlahi District, as in other parts of Terai is that about 81% of the total annual rainfall is delivered by monsoon in four months from June to September (based on 1987 to 1989 records). Annual precipitation from 1987 to 1989 recorded at the Malangawa Meteorological Station (Station No.1120) only was available to SAIP during preparation of the report on personal request basis. The average rainfall for those 3 years is 1878 millimeters.

1.8 Population

There were about 398,766 people in Sarlahi District in 1981 giving an average population density of about 317 persons per km^2 (SYBN, 1991). About only 10 % of the population in Sarlahi District were living in an urban setting in 1981.

1.9 Agriculture

The principal crops grown in Sarlahi District are paddy, maize, millet, wheat, barley, oilseeds, potato, tobacco, sugarcane, pulses and others. Statistics for crops are listed in Table 1 (Agricultural Statistics of Nepal, 1990).

Table 1. Principal crops harvested in 1988-1989 in Sarlahi (ASN,1990).

Crop	Area (Ha)	Yield (Kg/Ha)	Production (M.ton)	Annual Ave. Retail Price (Rs./Kg)
Paddy	53070	2321	123150	5.78
Maize	8990	1778	15980	4.73
Millet	680	1206	820	5.88
Wheat	14850	1500	22270	5.91
Barley	180	1000	180	NA
Oilseed	4200	719	3020	13.83
Potato	900	9056	8150	4.68
Tobacco	910	659	600	55.15
Sugarcane	4100	30000	123000	NA
Pulse	200	500	100	NA

Sarlahi District contains 73,710 Ha of Agricultural land (ASN,90) and little more than half is irrigated (Table 2). Ground water will provide a large part of the water to irrigate the potential irrigation land.

Table 2: Status of agricultural land in Sarlahi District (ASN, 1988/89)

ITEM		AREA (ha)	Percentage
Total agriculture land		73,710	100
Potential irrigable land		73,521	99.70
Current irrigation practices	By monsoon	18,561	25
	Year around	21,212	29
	Total	39,773	54
Remaining potential year around irrigation land		52,309	71

1.10 Acknowledgments

Most of the information compiled and presented in this report are that of the UN project wells which was drilled by the Ground Water Resources Development Board office in Birgunj. One deep well drilled by GWRDP is also presented in this report. The pumping tests made by GWRDP, Birgunj has provided a wealth of valuable information necessary for aquifer evaluation.

The work of the staff engaged in hydrogeological work in Birgunj, both in the field and office, is highly appreciated. Mr. J.M. McNellis, Chief Technical Adviser to NEP/86/025 has critically reviewed this report which is greatly appreciated. Thanks are also due to Mr. Y.L. Vaidya, Deputy Directer General, Dept. of Irrigation, HMG/N, for his moral support .

2. GEOLOGY, LITHOLOGY AND WATER SUPPLY

Investigation of ground water in the Terai is incomplete without a comprehensive description of the geologic framework of the area. However, this project focused on just the Terai and did not consider the relationship of the area with the Siwalik Hills (Tertiary formation) just north of the Terai. Therefore, the discussion of geology is cursory.

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

The deposits are placed in two groups for hydrologic and lithologic purposes, the Bhabar Zone deposits and the Terai Plain deposits. The division is not easily defined in the subsurface because of the nature of the sedimentation processes.

The 20 successful UN investigation wells drilled during this project, and one GWRDB deep tube well provide important information on the composition and distribution of these Terai deposits.

2.1 Lithological Cross Sections

The well locations and traces of lithological cross-sections for Sarlahi District are presented in Figure 4. Six self explainatory cross-sections in Figures 5 - 10 are presented that should provide readers to understand and gain an appreciation for the rapid changes within the subsurface of the Terai.

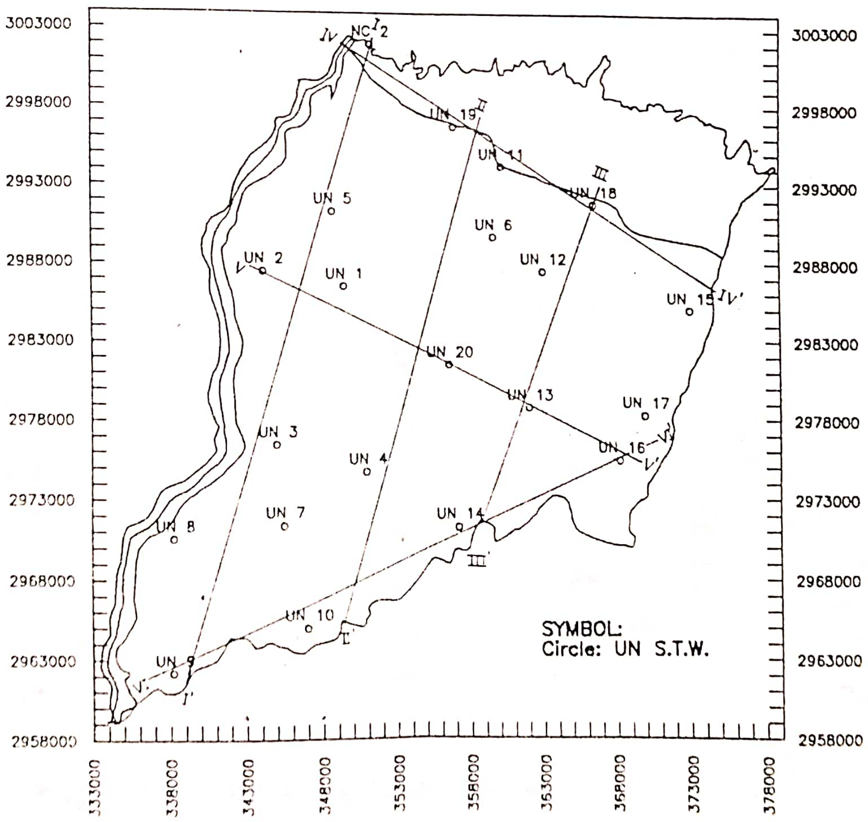

Figure 4. Map showing locations of wells and lithological cross-sections.

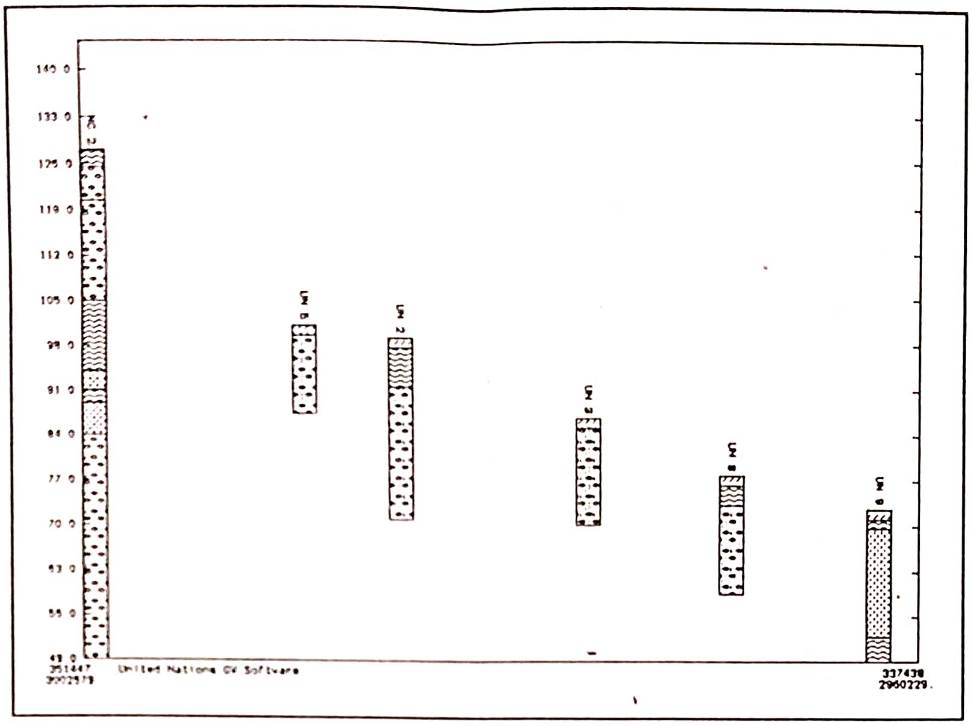

Figure 4. Lithological cross-section I-I'.

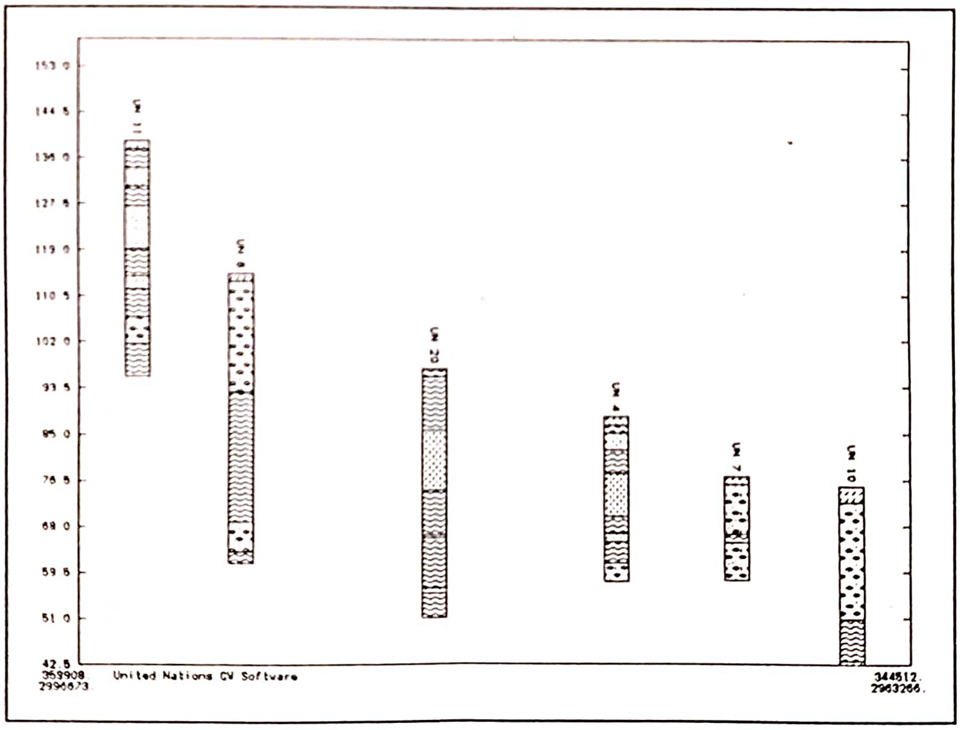

Figure 5. Lithological cross-section II-II'.

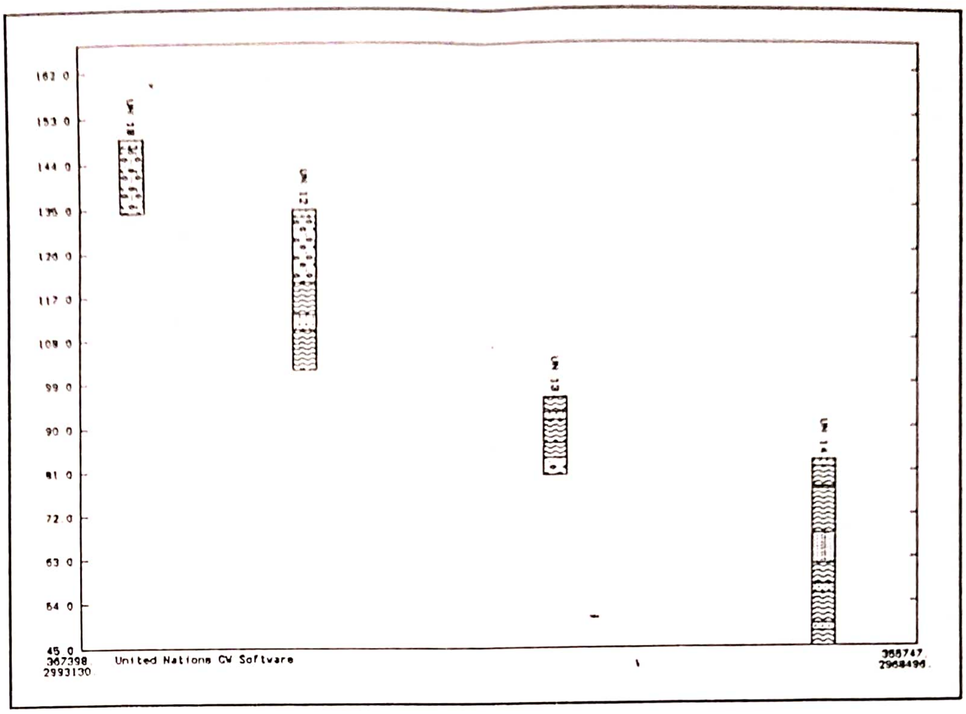

Figure 6. Lithological cross-section III-III'.

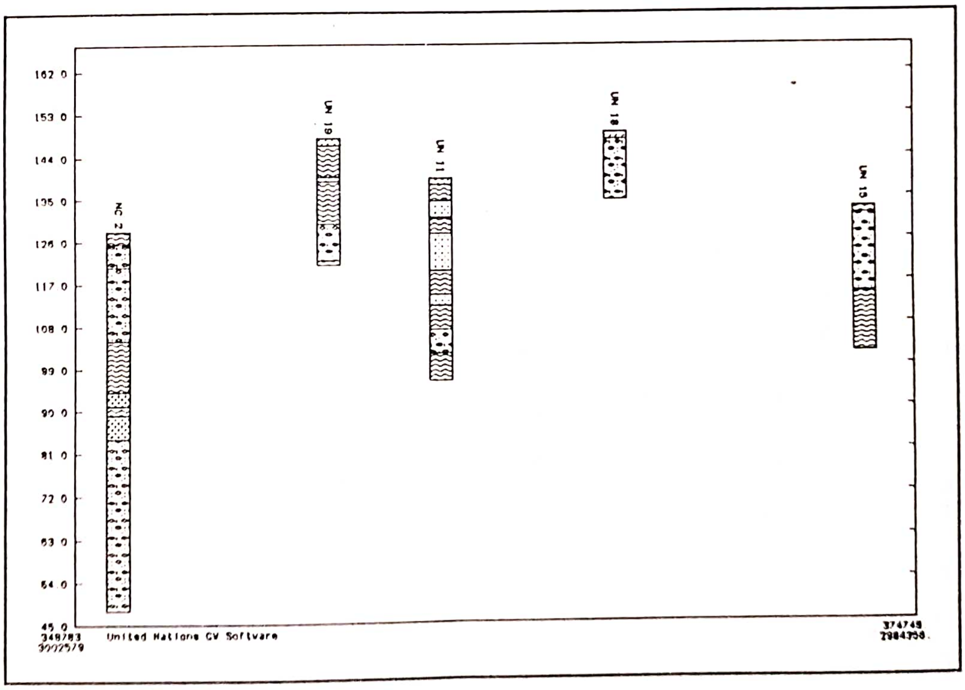

Figure 7. Lithological cross-section IV-IV'.

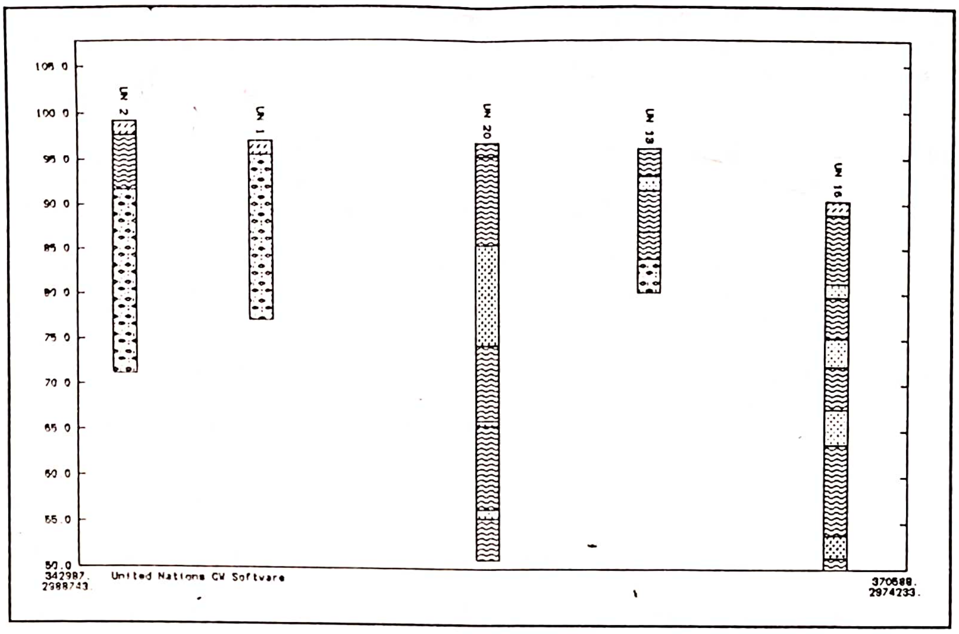

Figure 8. Lithological cross-section V-V'.

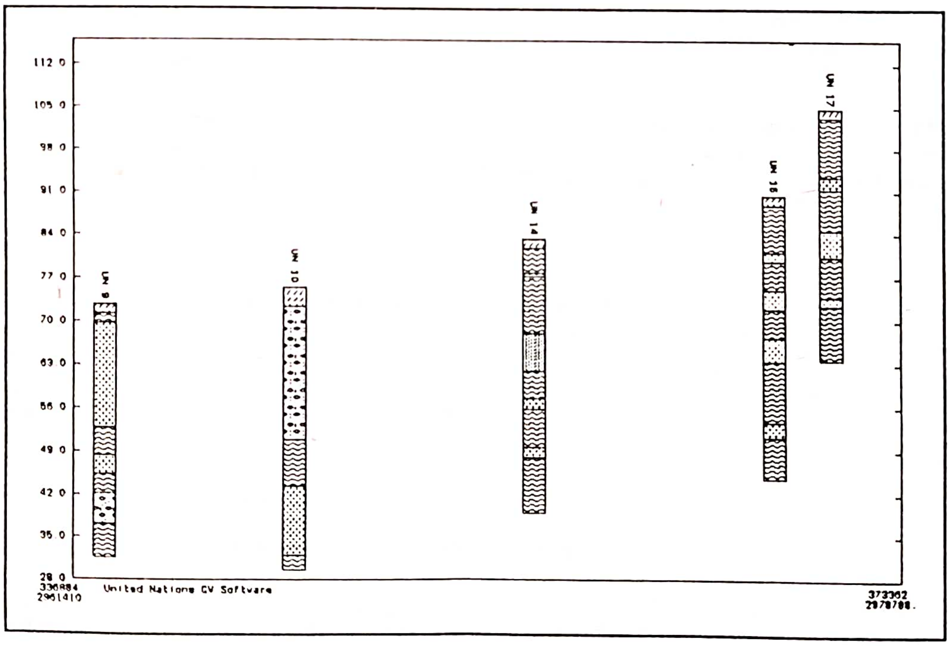

Figure 9. Lithological cross-section VI-VI'.

The 20 UN investigation wells drilled towards end (1990) of the current project in Sarlahi, and one Nippon Koei well drilled in the 1985 provide important information on the composition and distribution of these Terai deposits. Individual well logs are shown in Appendix B.

No attempt has been made to connect permeable layers in the cross-sections. This is not warranted as the Quaternary deposits near the Siwaliks and across the Terai plain is traversed by many present rivers and buried channels of rivers of the past. The lithology of the sediments changes rapidly over very small distances.

However, it is generally interpreted that the grain size of the Terai sediments appear to decrease slightly from north to south which is also confirmed in Sarlahi from the above cross-sections.

With respect to the quality and quantity of information, one may expect that in most of Sarlahi District at least 5 meters of saturated sand and/or gravel may be found within a depth of 50 m from ground level. Thus, a shallow well to supply drinking water to villages can be constructed without too much uncertainty. It is difficult to say whether large capacity irrigation wells can be recommended with equal certainty without a more detailed exploration program. The chances of finding excellent aquifers at shallow depths are tied to locating coarse sediments.

2.2 Bhabar Zone deposits

2.2.1 Lithology, distribution, and thickness

Bhabar Zone deposits are found, but are not continuous, at the surface along the base of the Siwalik Hills at the north edge of the Terai and also along major rivers transecting the Terai. The outcrop area of Bhabar Zone is estimated at 200 km2 in Sarlahi (LRMP, 1986; Tillson, 1985), and is a principal recharge area for the ground water reservoir of the Sarlahi Terai.

The Bhabar is derived principally from erosion of the Siwalik Formations found in the Siwalik Hills. Streams cut through the hills, abruptly debauch onto the much flatter Terai which is the north portion of the Ganges plain, and dump their sediment as alluvial fans. Through time these fans coalesce and are covered with other sediments and comprise the Bhabar Zone and it may be found at depth south of the Siwalik Hills.

The Bhabar is very poorly sorted and contains a large proportion of coarse grained material, ranging in size from sand to boulders. There are intercalated finer sediments as well. Thickness ranges from a few meters to more than a hundred meters.

2.2.2 Water supply

Wells screened in the Bhabar adjacent to the Siwalik Hills experience water level fluctuations large enough to place water levels below the lifting capability of commonly used centrifugal pumps. Therefore, very few STW obtain water from the Bhabar. Yields from deep tube wells (DTW) in Sarlahi District which may obtain water from the Bhabar were not measured during this investigation.

2.3 Terai Plain deposits

2.3.1 Lithology, distribution, and thickness

Throughout the Terai a thick sequence of clastic sediments, the Terai Plain deposits, has been and is being deposited. These sediments are at the surface except for the outcrop area of the Bhabar Zone. These deposits cover about 859 km2 (LRMP, 1986) in Sarlahi and their thickness may exceed 1000 meters along the Indian border.

The Terai Plain sediments are comprised of rock material eroding from the Siwalik Hills and the mountains to the north. Sediment particles range in size from clay to gravel and the proportions vary widely. However, they generally comprise more clay, silt, and fine sand than sand and gravel. The coarser size fractions appear to be lenticular in cross section and are described as sand lenses or sand and gravel lenses contained in finer sediments.

2.3.2 Water Supply

There were a reported 1261 STW in Sarlahi in mid-1986 (GDC, 1987). These wells are in the Terai Plain. In addition, there were a large number of dug wells. Some wells provide water for drinking or domestic purposes. Others, STW in particular, provide irrigation water. Reported yields range from less than five l/s to more than 50 l/s.

2.4 Drilling

Lithological logs and other available information were collected on 21 drilled wells including 1 DTWs drilled by Nippon koe. This project drilled 20 investigation wells, were considered successful. The maximum and minimum drilled depths of the project wells are 53.34 m and 14.63 m respectively and the average drilling depth is 31.4 m. The most pertinent data on the project wells and other selected wells are presented in Table 3 including the pump tested wells. Aquifer or pumping tests were conducted on a total of 20 wells. Fifteen of the pumping tests are considered successful.

Table 3: List of Tubewells 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	Aquifer Thickness (m)	Aquifer as Percent of depth (m)	Drilling Date	Well Diameter (inch)	Water Level BGL (m)
			Village Name	Landsat Co-ordinates (2)											
				X	Y										
1	SLS01.LTH	UN 1	SITAPUR	349410.	2986400.	97.00	19.80	6.1	8.53-14.63	Slotted	18.3	92.4	23-3-1990	4	-3.78
2	SLS02.LTH	UN 2	HAJARIYA	344115.	2987400.	99.20	28.05	6.1	14.70-20.80	,,	20.5	73.3	28-3-1990	4	-4.00
3	SLS03.LTH	UN 3	BHAVANIPUR	344950.	2976400.	86.70	16.46	2.8	7.35-10.10	,,	15.0	90.9	2-4-1990	4	-1.68
4	SLS04.LTH	UN 4	AURAHI (CHAINP	350900.	2974650.	87.90	30.18	8.0	10.50-18.50	,,	15.8	52.4	6-4-1990	4	-7.30
5	SLS05.LTH	UN 5	SHANKARPUR	348650.	2991200.	101.20	13.72	4.7	8.40-13.14	,,	12.2	89.1	2-4-1990	4	-1.65
6	SLS06.LTH	UN 6	HARIPUR	359600.	2989600.	114.50	53.34	8.0	32.35-43.50	,,	24.7	49.4	8-4-1990	4	-5.49
7	SLS07.LTH	UN 7	SHISHAUT	345460.	2971350.	77.10	19.20	8.2	5.00-13.25	,,	16.2	84.2	7-4-1990	4	-2.45
8	SLS08.LTH	UN 8	BAIRIYA	338260.	2970550.	78.00	18.29	8.6	5.00-13.57	,,	13.7	75.0	14-4-1990	4	-0.91
9	SLS09.LTH	UN 9	BALARA	338200.	2962200.	72.70	41.14	5.5	10.50-16.01	,,	24.9	60.5	18-4-1990	4	-2.82
10	SLS10.LTH	UN 10	MADHUBAN	346990.	2964970.	75.30	45.73	8.2	5.00-13.25	,,	32.6	71.4	24-4-1990	4	-1.50
11	SLS11.LTH	UN 11	NAWALPUR	360180.	2994130.	148.00	43.46	6.1	31.40-37.40	,,	18.9	43.5	16-4-1990	4	-0.33
12	SLS12.LTH	UN 12	BAILBAS	363000.	2987400.	125.00	32.61	6.1	7.90-14.00	,,	16.2	49.6	23-4-1990	4	-1.42
13	SLS13.LTH	UN 13	POKHARIYA	361990.	2978700.	100.00	15.85	2.7	12.00-14.75	,,	5.2	32.7	14-4-1990	4	-0.91
14	SLS14.LTH	UN 14	MALANGAWA	357150.	2971200.	83.10	44.20	5.5	16.10-21.60	,,	10.0	22.7	6-4-1990	4	-1.00
15	SLS15.LTH	UN 15	SRINAGAR	373000.	2985000.	132.60	31.08	6.1	12.40-18.50	,,	16.8	54.0	27-4-1990	4	-3.20
16	SLS16.LTH	UN 16	JINGARAWA	368200.	2975400.	90.30	45.70	2.9	15.07-17.92	Slotted	10.9	23.9	23-4-1990	4	-1.73
17	SLS17.LTH	UN 17	BASANTPUR	369900.	2978260.	104.80	41.15	3.6	9.36-12.91	,,	7.9	19.2	17-4-1990	4	-0.58
18	SLS18.LTH	UN 18	LALBANDI	366500.	2991720.	150.00	14.63	3.1	10.97-14.04	,,	13.1	89.7	8-5-1990	4	-1.14
19	SLS19.LTH	UN 19	HARION	356900.	2996700.	145.00	27.12	6.1	18.90-24.99		8.9	32.7	17-5-1990	4	-11.47
20	SLS20.LTH	UN 20	SIRSIYA	356500.	2981400.	96.70	45.70	11.0	10.60-21.60		12.6	27.6	1-7-1990	4	-2.51
21	SLD01.LTH	NC 2	KARMAIYA	351250.	3002000.	128.00	80.00	25.0	50.00-75.00		64.5	80.6	10-11-1985	8/12	

1) Dug Wells are not included in this table due to lack of lithlogical information.
2) (m) Meter
3) X and Y co-ordinates are taken from the 1:50,000 map of Nepal, a composite of Landsat Imagery (NRSC, 1984). The co-ordinates were read with the help of project supplied digitizer.

The 20 UN wells listed in Table 3 are further analyzed to Table 4. The percentage of aquifer (permeable material) found in each well and for all wells is listed in Table 5.

Table 4. Analysis of Wells Data in Table 3

Item	For UN-STW
Total no. of wells	20
Total drilled depth	627.1 m
Average depth per well	31.4 m
Total screen used	119.9 m
Average screen used	6.0 m
No. of wells with screen	20
No. of wells without screen	0

Table 5. Analysis of Permeable Thickness from Table 3

Item	For UN-STW
Depth of calculation	50.0 m
Cumulative depth	624.1 m
Total permeable thickness	314.5 m
Average percent of permeable thickness	50.4 %

Note:

Since there is only one deep tubewell, it is excluded during analysis of well data and permeable thickness.

3. HYDROLOGIC PROPERTIES OF WATER-BEARING MATERIALS

Predictions about the behavior of the ground water reservoir in Sarlahi District are dependent on knowledge of the values of the hydraulic constants of the aquifer. . These hydraulic properties are in turn dependent upon dimensional and geological parameters. The parameters needed are transmissivity (T), storage (S), and leakage (P'). 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 and the ability to transmit water by its transmissivity. A ground water reservoir may include semiconfining beds and the ability of these beds to transmit water vertically is measured by leakage.

3.1 Pumping tests

Hydrogeologists have several ways to determine the hydraulic constants of aquifers and for NEP\86\025 the method is called a pumping test. A pumping test is performed to learn aquifer properties of T, S, and sometimes P. Twenty pumping tests were begun and completed. The pumping tests are of marginal quality and the numeric results they provide should be used with caution.

Fifteen aquifer tests were analyzed to determine the storage coefficient, the transmissivity, and the hydraulic conductivity of the aquifer. The test data were analyzed by the Theis and the Jacob methods. Each test was analyzed by the preceding methods in an attempt to arrive at aquifer coefficients judged to be most nearly correct. Graphs of the individual pumping tests are shown with observed data and a computer-fitted curve in Appendix C.

Table 6.--Aquifer hydrologic properties from pump tested wells.

S. No.	Well Identity	Trans-missivity (M2/day)	Aquifer thickness (M)	Hydraulic conductivity (M/day)	Aquifer type	Pumping Test Date	Storage Coefficient	Constant Pumping Rate (l/s)	Distance From Pumped Well (m)	Static Water Level (m)
1	UN 1	7022	18.3	383.71	G	23-3-1990	0.40E-14	20.00	41.65	-3.18
2	~~UN 2~~	12688	20.5	618.92	S+G	28-3-1990	0.12E-19	20.00	72.60	-4.03
3	UN 3	1278	15.0	85.20	S+G	2-4-1990		25.00		-2.30
4	UN 4	146	15.8	9.20	G	6-4-1990	0.30E-04	6.25	19.00	-3.25
5	UN 6	113	25.9	4.36	S+G	8-4-1990		2.00		-4.27
6	UN 7	946	16.2	58.39	G	7-4-1990	0.56E-02	25.00	4.20	-2.01
7	UN 8	4920	13.7	359.12	G	14-4-1990		25.00		-2.03
8	UN 9	5035	13.1	384.35	S	18-4-1990		27.50		-2.47
9	UN 10	427	32.6	13.09	S	24-4-1990		17.00		-2.25
10	UN 12	1583	16.2	97.71	S	23-4-1990		12.00		-2.05
11	UN 13	541	5.2	104.03	S	14-4-1990	0.84E-12	1.00	5.80	-2.94
12	UN 14	91	10.0	9.10	S	6-4-1990	0.13E-03	1.50	4.28	-4.04
13	UN 16	54	10.9	4.95	S	23-4-1990		1.50		-1.87
14	UN 17	43	7.9	5.44	G	17-4-1990	0.44E-08	1.03	2.88	-2.80
15	UN 20	2527	12.6	200.55		1-7-1990		12.00		-2.51

4. GROUND WATER

The discussion on ground water will cover general ground water concepts and the acquisition and interpretation of data in this ground water investigation in Sarlahi District as well as in the larger context of project NEP/86/025.

4.1 Source

The primary source of ground water in Sarlahi District is local precipitation. For example, ground water in the Bhabar Zone deposits and the Terai Plain deposits is derived from precipitation that falls on Sarlahi and the watersheds of the streams that traverse Sarlahi, 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 11 illustrates the relationship between precipitation and water levels in selected wells. Rapid rise of water levels in response to the monsoon is shown.

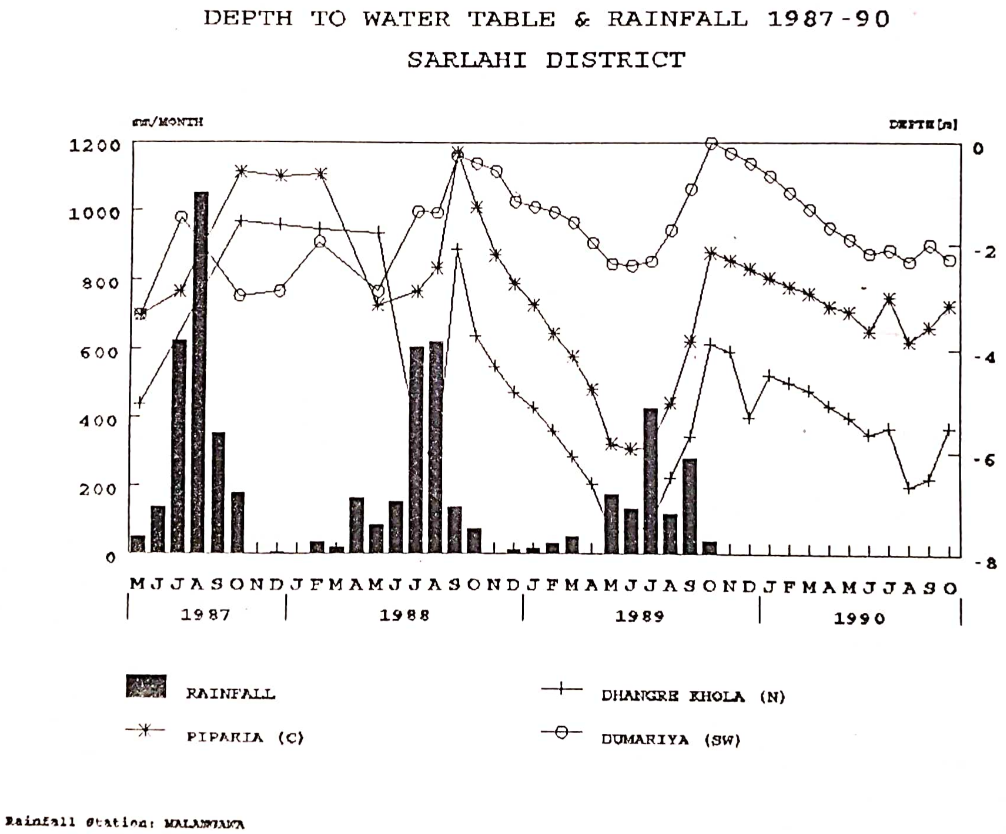

Figure 11. Bar chart showing precipitation at Malangawa, and graphs of water level in three observation wells in Sarlahi District.

4.2 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 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 move freely through a coarse gravel under a low hydraulic gradient, but will move with extreme slowness through clay under a high hydraulic gradient.

Water level measurements in a number of geographically disbursed wells are the basis for several determinations in ground water hydrology. Figure 12 is a map of Sarlahi District showing the locations of the wells where water levels are measured regularly. Appendix D contains tables of water level measurements made by this project. Appendix E presents hydrographs of selected wells and Appendix F provides maps of depth to water and water level changes for 1988-89.

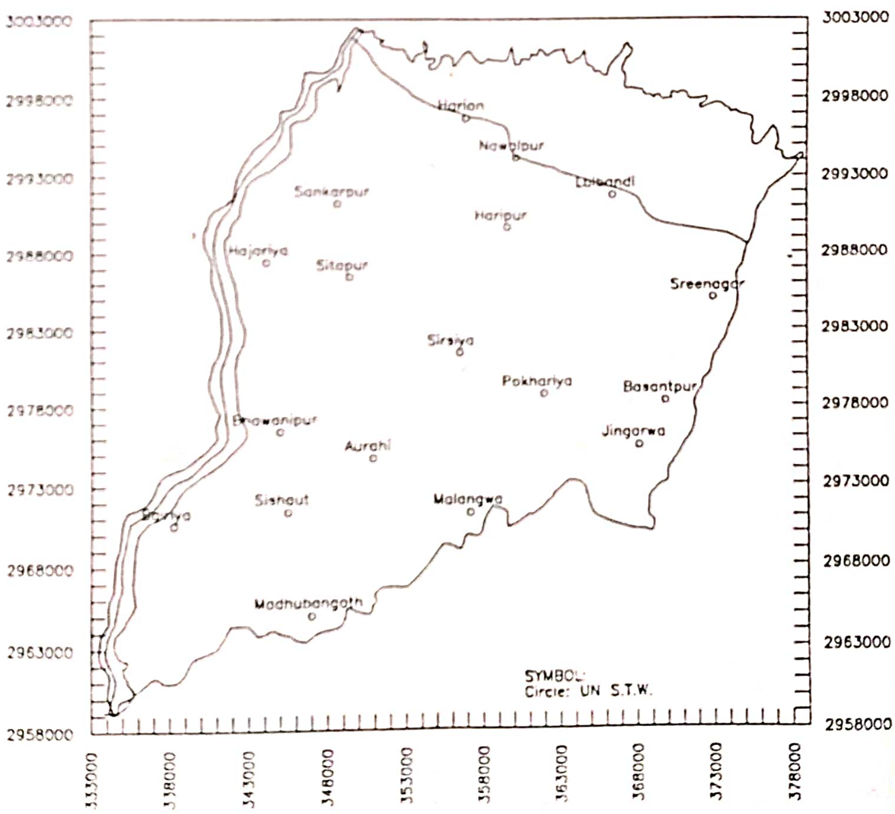

Figure 12. Map of Sarlahi District showing locations of wells water level measured on a regular basis.

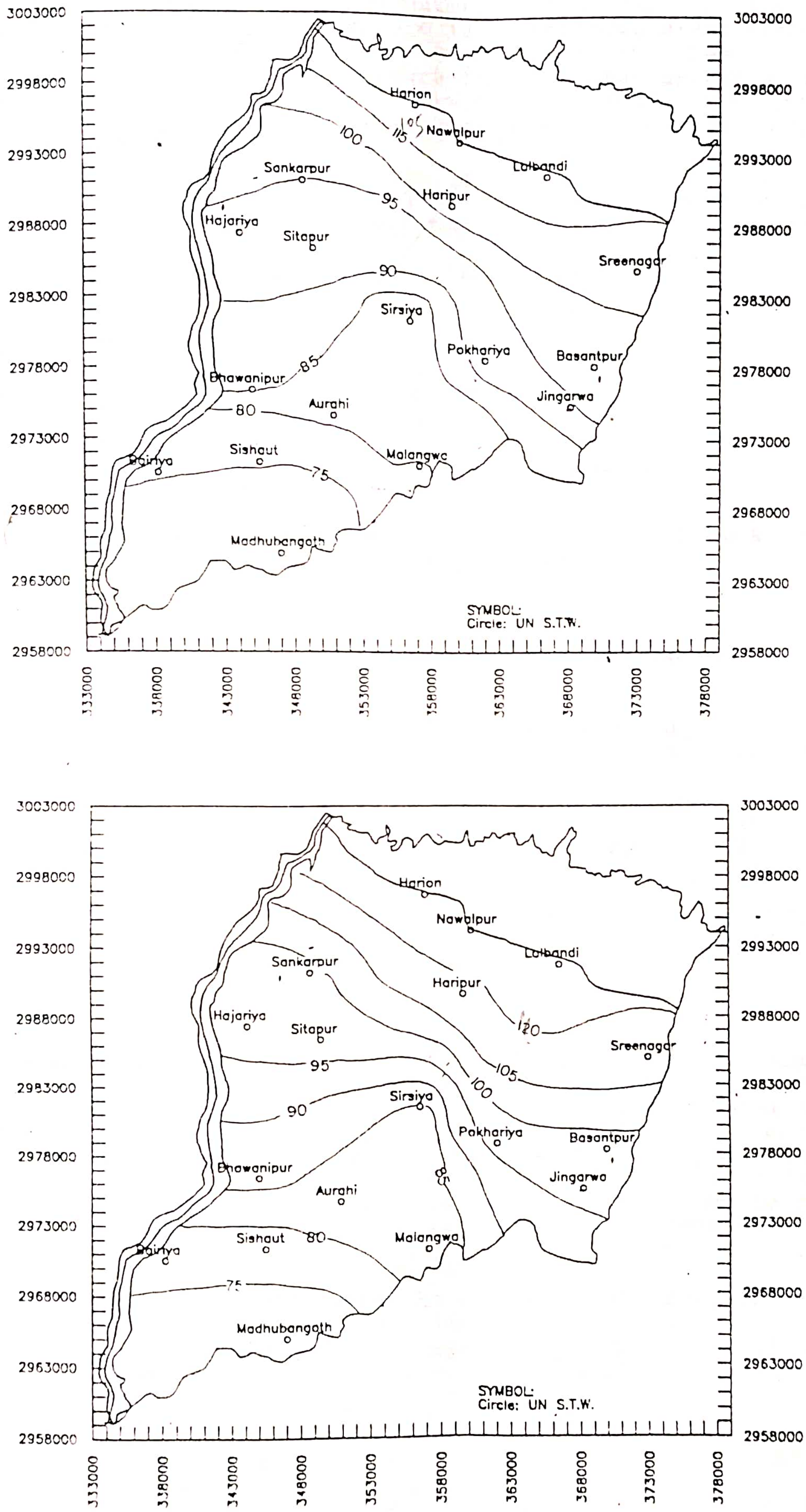

Figure 13. Maps showing contours of equal altitude water level, June (top) and September 1991 (bottom) in Sarlahi District.

The shape and slope of the water table in June and September 1991 in Sarlahi District are shown on Figure 13 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 north to south. The spacing of the contours indicates a hydraulic gradient of about 2 meters per kilometer on the north to .5 meter per kilometer on the south.

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,
T is the transmissivity
L is the length of the corss-sectional area, and
I is the hydraulic gradient.

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

$$v = KI/p$$

An estimate of the quantity of water moving as subsurface outflow to India is calculated using the following assumptions:

Average aquifer saturated thickness is the average % of coarse grained material in the STW, or 50.4 % of 31.4 meters, or 15.8 meters,
Assumed porosity of 15%,
Aquifer width (distance along border with India) 37 km,
Hydraulic gradient of .5 meter per kilometer, or 0.0005
Hydraulic conductivity of 83 m/day along border with India

Using these assumptions with the average saturated thickness of 12 meters, the volume of water flowing to India is 24,261 m3/day or 8.8 million cubic meter (MCM) per year at the rate of 0.28 m/day.

4.3 Storage

The total thickness of the Terai sediments in Sarlahi District is not known but if only the upper 50 meters are considered the volume of ground water in storage is quite large. The volume of drainable water is a function of thickness and specific yield of the saturated sediments. An average specific yield for sediments from a similar depositional environment and similar lithologies, the High Plains aquifer of the United States is .15 (Gutentag et.al., 1984). The drainable water in storage may be calculated by multiplying aquifer thickness, estimated specific yield and area of the aquifer.

The volume of drainable water in storage is not calculated because all the drainable water in storage cannot be recovered and used. The recoverable volume of water is site specific and depends on well construction and design, lithology, saturated thickness, hydraulic conductivity, specific yield and drainage time.

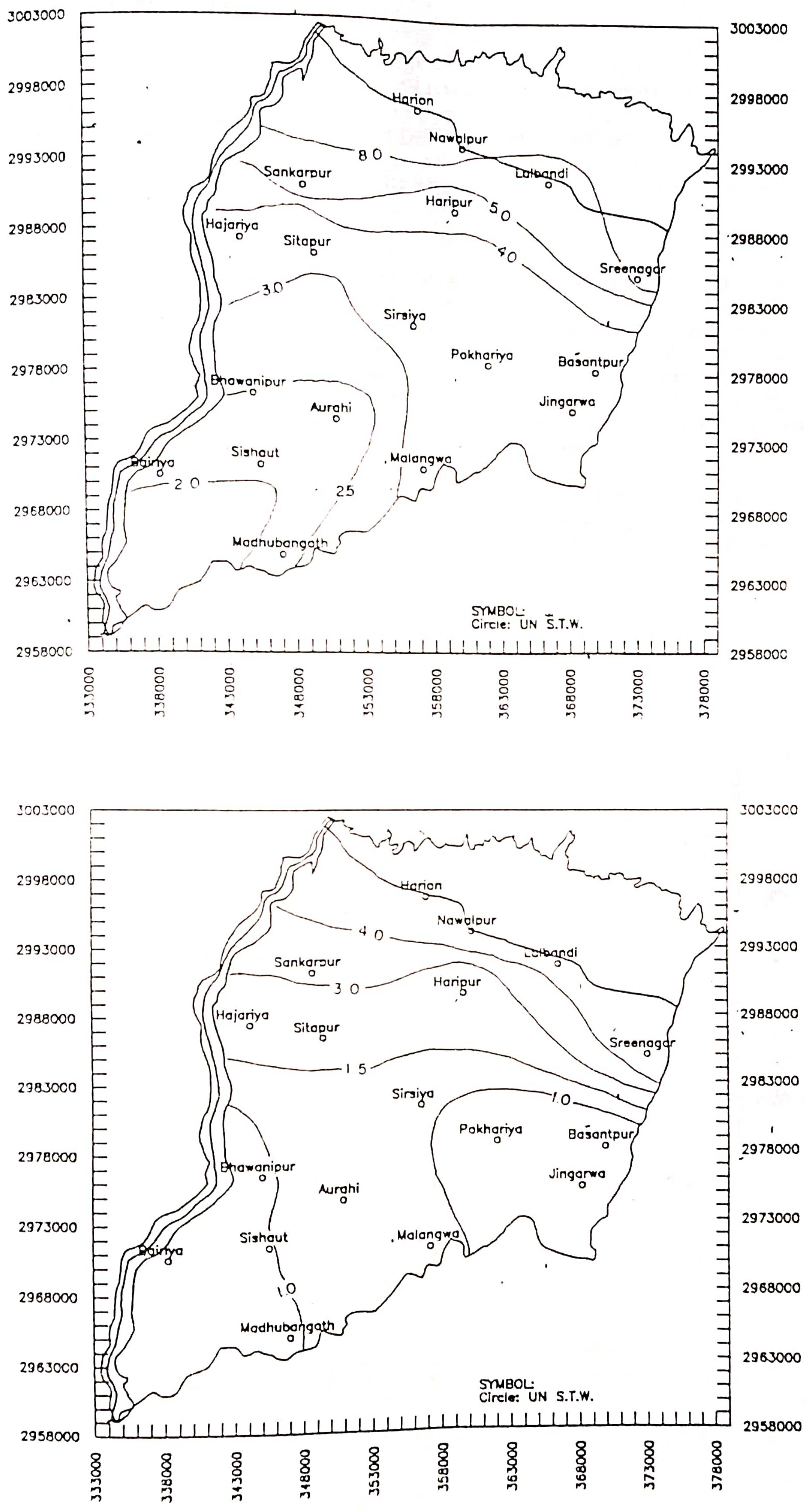

Figure 14. Maps showing contours of depth to water using shallow well in June (top) and September (bottom) 1991.

4.4 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 evapotranspiration. Water-level-change maps may illustrate, by minor fluctuations and trends, essentially static conditions in a relatively undisturbed aquifer.

Figures 14 is depth to water level maps for 1991. Figure 15 shows the water level change maps for 1991. The maps document changes within each year which are attributed primarily to seasonal variations. However, comparision of the maps points out the differences in population of wells used for water level measurements. Not only are the distributions of wells different but also the aquifer may be different. Dug wells tap the very first water encountered in the sediments while STW measurement reflect the water level of the aquifer where the screen is placed in the well.

Water level measurements provide extremely important information about the groundwater situation in the area. The hydrogeologist must be very careful as water levels from different aquifers may lead to incorrect conclusions and large errors.

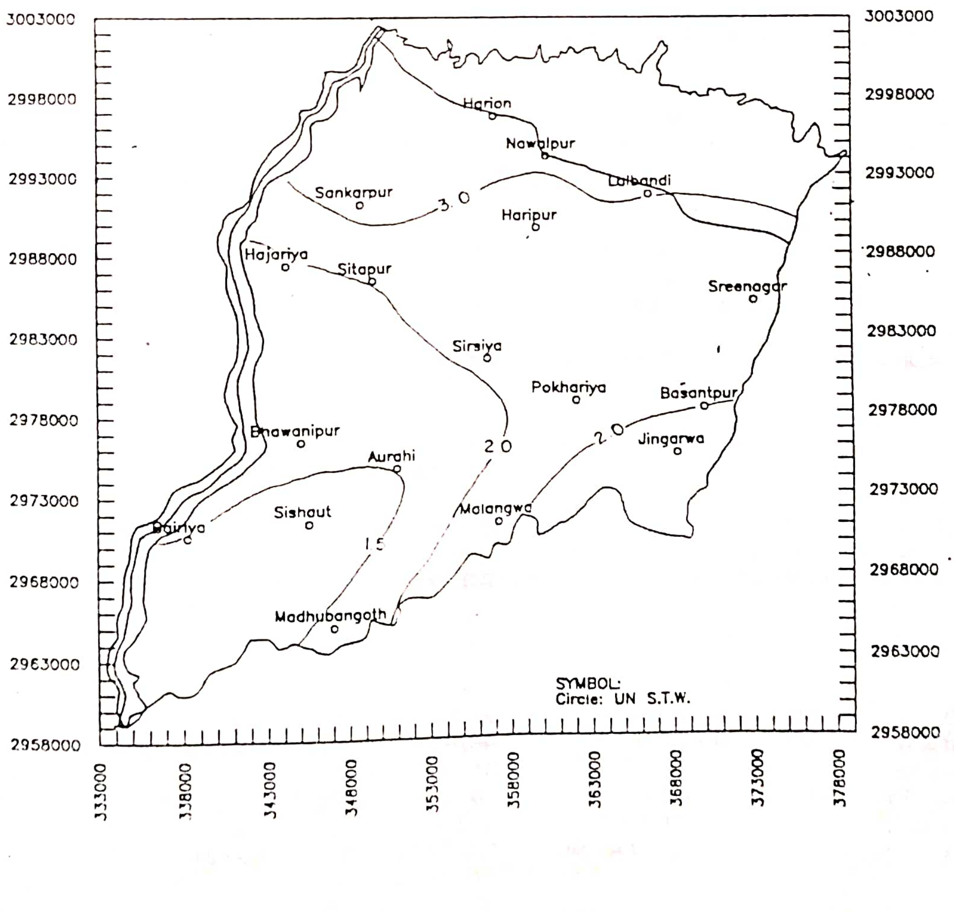

Figure 15. Maps showing pre to post monsoon water level in 1991.

4.5 Discharge

Ground water in Sarlahi District Terai is discharged from the aquifer by wells, evapotranspiration, subsurface outflow, and inflow to streams. The subsurface outflow from the district was determined in the section on movement of water. Measured data on the volume of discharge are not available but information can be derived from pumpage and evapotranspiration estimates.

4.5.1 Pumping By Wells

Pumpage records for irrigation wells are not available, however, an estimate of pumpage that would stress the aquifer may be calculated by assuming a specific number of irrigation wells, the number of hours each well is pumped in a year and the average yield of each well. The number of shallow wells in the Sarlahi District is 1261 (GDC, 1987) which is for the present purpose projected as 2000, 6 hours of pumpage a day for 360 days and an average discharge estimated at 10 l/s. These numbers give:

2000 wells * 2,160 hours * 3600 seconds * 10 liters per second
= 156 MCM potentially pumped per year in Sarlahi

At the present time the wells are not pumping 2,160 hours a year, perhaps only 300 hours a year, hence this hypothetical pumpage estimate is illustrative of the relatively large volume of water that could be pumped with minimal effect on the aquifer.

4.5.2 Evapotranspiration

Direct evaporation occurs in areas where the water table is near the land surface, such as along stream banks and in stream beds. The potential for evaporation is high during the rice growing season as the paddies are really large bodies of surface water during that time. Finally, during and after the monsoon the water levels are at or near the surface at many places in Sarlahi.

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.

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 1 m to 3.0 m of the fluctuation attributed to evapotranspiration, the specific yield of the saturated sediments is estimated at .15 and the area of Terai in the district is 1059 Km2. Thus:

1 m * .15 * 1059 * 1000 *1000 = 159 MCM of ground water potentially evapotranspired each year

Lowering the water table below the depth of most evapotranspiration processes would effectively permit the 159 MCM of ground water potentially evapotranspired each year to become recharge. This additional recharge would be available to irrigate crops.

4.6 Recharge

The aquifer in Sarlahi is recharged by subsurface inflow from stream valleys entering the district, by seepage losses from streams during high flow, by subsurface inflow from the Siwalik Hills 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. Percolation of rainfall to the water table is the principal recharge mechanism and discussed in some detail.

4.6.1 Subsurface inflow

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

4.6.2 Seepage Losses From Streams

Seepage into the aquifer may be substantial during high flow, however, no quantitative estimate was made.

4.6.3 Percolation From Rainfall

Percolation of precipitation into the aquifer is the primary recharge mechanism in Sarlahi. The Bhabar is particularly receptive to direct percolation to the water table because of the large size of the particles comprising the deposits. However, the balance of the Terai Plain is also receptive to direct percolation of precipitation to the aquifer. Finally, the Siwalik exposures contribute additional recharge through percolation to the aquifer. Total annual rainfall for the Bharbar Zone is 1879 mm and for the Terai Plain is about 1393 mm (Duba 1982).

Three estimates of recharge from precipitation are calculated. The first method utilizes data from Duba (1982); the second method assumes 10% of rainfall is recharge; the third method assumes a specific yield and uses water table fluctuations. Each method uses an area of 1059 Km2 for the Sarlahi Terai.

Method 1:

Duba (1982) estimated 32.6% of the rain that falls on the Bhabar and 15.4% that falls on the Terai plain would percolate to the aquifer. No estimate of recharge has been made for the Siwalik. The calculation for recharge using Duba estimates:

m3 of recharge = annual rainfall in m * area Km2
* % to aquifer

For Bhabar: 200 Km2
1.9 m * 200 * 1000000 m * .326 = 123 MCM recharge

For Terai plain: 859 Km2
1.4 m * 859 * 1000000 m * .154 = 185 MCM recharge

Recharge = Bhabar + Terai Plain = 308 MCM per year

Method 2:

A minimum 10% of rainfall becomes recharge.

For Bhabar:
1.9 m * 200 * 1000000 m * 0.1 = 38 MCM recharge

For Terai plain:
1.4 m * 859 * 1000000 m * 0.1 = 120 MCM recharge

Recharge = Bhabar + Terai plain = 158 MCM recharge

Method 3:

Utilizes specific yield of 15%, a pre-post monsoon water level fluctuation of 1 m and the area of the Terai.

Recharge = .15 * 1 m * 1059 Km2 = 159 MCM per 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 any of the methods of estimated recharge and the subsurface outflow into India of about 8.8 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 (currently a minor component).

4.6.4 Summary of ground water system

In a ground system, recharge (addition of water to the aquifers), storage (retention of water in the aquifers), and discharge (diversion of water from the aquifers) are directly related to each other. When recharge exceeds discharge, (during the monsoon period) the quantity of water in storage increases and the water table rises. Conversely, when discharge exceeds recharge, (during the dry period) the quantity of water stored decreases and the water table declines. The monsoon raises the water table as the aquifer is 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, evapotranspired, and moves in the subsurface toward the south.

The water level change maps reflect the recharge, change in storage and discharge of the Sarlahi ground water system. The changes in water level appear to be due to seasonal variations. As agricultural practices replace the forests, no discernible effect has been made on seasonal water levels. Therefore, the ground water system in Sarlahi is maintaining a quasi-equilibrium state.

The recharge and discharge estimates are reasonable. Table 7 brings these numbers together. The estimates of recharge are large and but balanced by the discharge by evapotranspiration. The evapotranspiration represents ground water that could be pumped for agricultural purposes and far exceeds the volume of water flowing to India in the subsurface.

Table 7. Estimates of ground water recharge and discharge in Sarlahi District.

ITEM	RECHARGE/YEAR	DISCHARGE/YEAR
Recharge estimates		
Method (1)	308 MCM	
Method (2)	158 MCM	
Method (3)	159 MCM	
Pumpage estimate		156 MCM
Outflow to India estimate		8.8 MCM
Evapotranspiration estimate		159 MCM

Information on recharge, storage and discharge of the ground water system in Sarlahi District is not complete. Several of the data components have not been measured or observed. However, estimates have been made for some major components with the thought that the estimates may be refined as data are collected in the future. Other components are not known nor estimated as their influence will become measurable during development of the ground water system. Table 8 lists the status of data components required to describe the Sarlahi ground water system.

Table 8. Status of components required to describe Sarlahi ground water system.

COMPONENT	AVAILABLE	M(measured) E(estimated)	RELIABILITY	AREAL DISTRIBUTION
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 IRRIGATION WELL FEASIBILITY

Areal delineation of feasibility of SIW in an area is a major goal of the project. The criteria defining a SIW are listed below:

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

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

Figure 16 shows the areas of probable SIW in Sarlahi District. Contours of depth to water have not exceeded 5 m during the dry season in the area shown since the project began. The depth to water criterion is the most important hydrologic constraint in the above definition of a SIW. Wells in the Terai 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 m. Thus, the dynamic water level of a well during the dry season should be within the suction limit of lift of a centrifugal pump i.e. water level must be less than 7 m below ground level or more accurately below the pump level. If the 5 m depth to water contour represents the depth to water in most dry seasons there should be 2 m of drawdown to be exceeded before a well would cease to produce irrigation water in the designated areas.

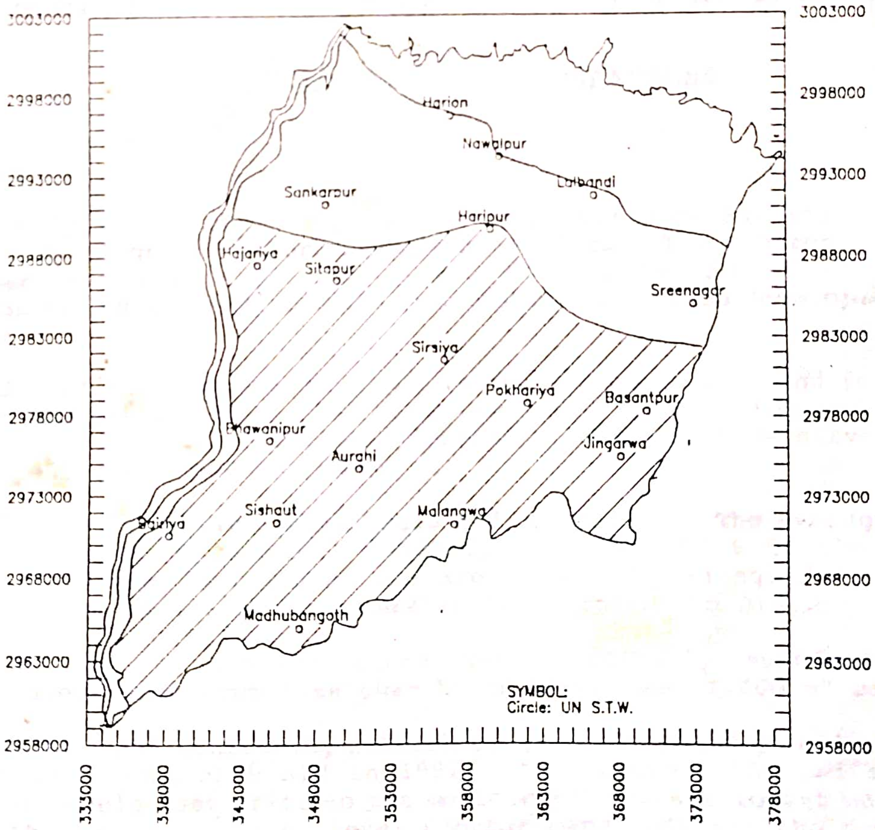

Figure 16. Map showing probable area (shaded pattern) of shallow irrigation wells.

Wells drilled to 40 m should find about 12 m 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 areas but does not guarantee success at each and every well location within those areas.

Discharge of the tube well should be adequate for irrigation, which is considered to be a yield of 3 to 5 l/s or more. Individual farms in Sarlahi averaged 1 ha in area in 1990 (SPBN). A well that pumps 5 l/s could cover 1 ha with about 5 centimeters (cm) of water in 33 hours. Thus the average farm could be irrigated with such a well. However, it is questionable if average size farms in Sarlahi are economically viable, even with the technology limited by the SIW definition. The limiting factor, economically, is the average size of a farm.

6. UTILIZATION OF GROUND WATER

Ground water in Sarlahi District is utilized for domestic, municipal, livestock, business, and industrial purposes but the use which seems destined to have large increases in the future is for irrigation of crops. Table 8 indicates 29 % of potential irrigation land in Sarlahi is irrigated the year around, leaving 71 % or about 52,309 hectares that could be irrigated the whole year. The pressure for increased food production in Nepal by an increasing population will require more and more year around irrigation.

7. SUMMARY AND RECOMMENDATIONS

7.1 Summary

The study of the shallow ground water resource of Sarlahi 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 Spring of 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 pumping tests.

There were 20 drilled wells begun and completed. The average depth of the wells was about 32 meters. Slightly more than 50 % of the sediments encountered were sand and gravel and are considered an aquifer. There is relatively little variation in permeable deposits in the District.

Out of 20, 15 pumping tests were marginally successful. The transmissivities range from less than 50 to more than 12,000 m2/day.

The water level monitoring network progressed from dug wells in 1987 to project STW with some ADBN 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 north to south with a gradient of about 0.5 meters per kilometer.

The aquifer in Sarlahi is recharged primarily by rain 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 Terai Plain is also receptive to percolation of precipitation to the aquifer. As much as 308 MCM per year may potentially be available for recharge although a minimum estimate of about 158 MCM is also calculated.

Hypothetical pumpage of 156 MCM per year is calculated from 2000 wells pumping 10 l/s for six hours each day. Evapotranspiration may be as much as 159 MCM. The estimated 8.8 MCM of ground water flowing to India is quite small compared to the recharge and evapotranspiration potentials.

The water level change maps reflect the recharge, change in storage and discharge taking place in the Sarlahi 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.

7.2 Recommendations

Ground water in Sarlahi 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. This report provides valuable data for planning and continuing development of the ground water resource but irrigation development in a specific area should include additional investigative wells and additional well designed pumping tests to help maximize success.

Water level measurements provide extremely important information about the ground water situation in an area and must be continued on a long term basis. A hydrologist must be very careful as water levels from different aquifers may lead to incorrect conclusions and potentially large errors in judgment.

8. GLOSSARY OF TERMS

Aquifer: A rock formation, bed, or zone that contains water that is available o 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.

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 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.

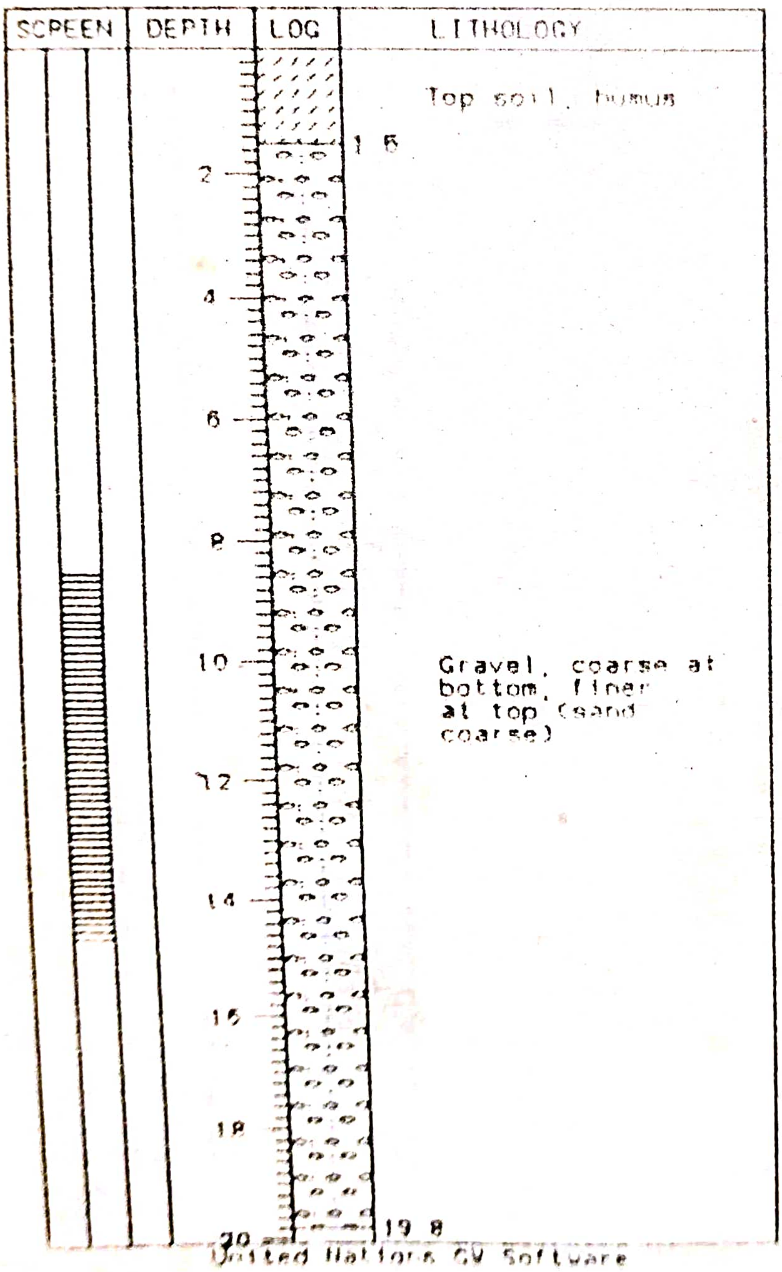
(d) Reports on mathematical modelling.

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

APPENDIX B
LITHOLOGICAL LOGS

Well No UN 1	Location SITAPUR
Elevation 97 0	x = 349410 y = 2986400
Method of Drilling Rig	
Drilling Dates 23 3 1990 - 27 3 1990	
Total Depth 19 80	
Comments Well size 4" Screen position 8 53 - 14 63 m Screen type Slotted M P 0 60 m	

W E L L L O G

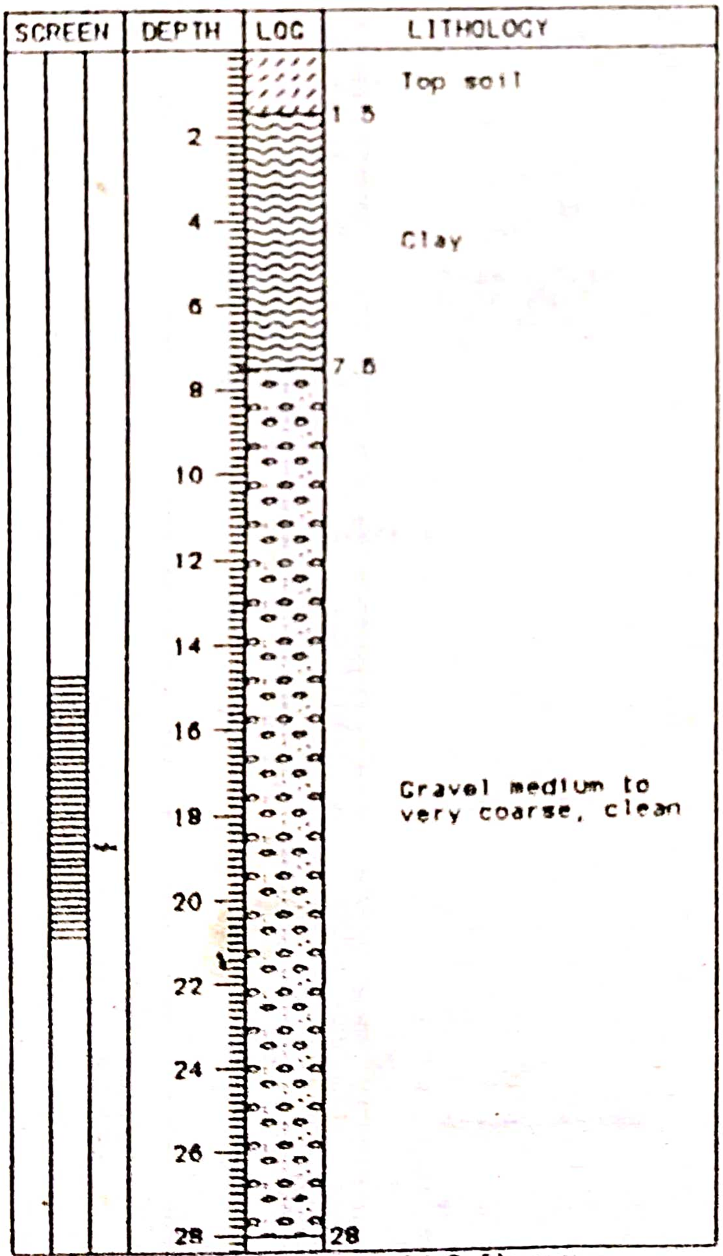


Date 19 4 90
Capacity: 20 l/s
Duration: 240 min
Transmiss. 7066 m2/day
Method . Theis
SWL -3 55 m
DWL -5 27 m

B-1. Well log of UN 1.

Well No UN 2	Location: HAJARIYA
Elevation: 99 2	X = 344115 Y = 2987400
Method of Drilling: Rig	
Drilling Dates: 28 3 1990 - 1 4 1990	
Total Depth: 28 05	
Comments: Well size: 4" Screen position 14 7 - 20 8 m Screen type Slotted M P 0 40 m	

WELL LOG



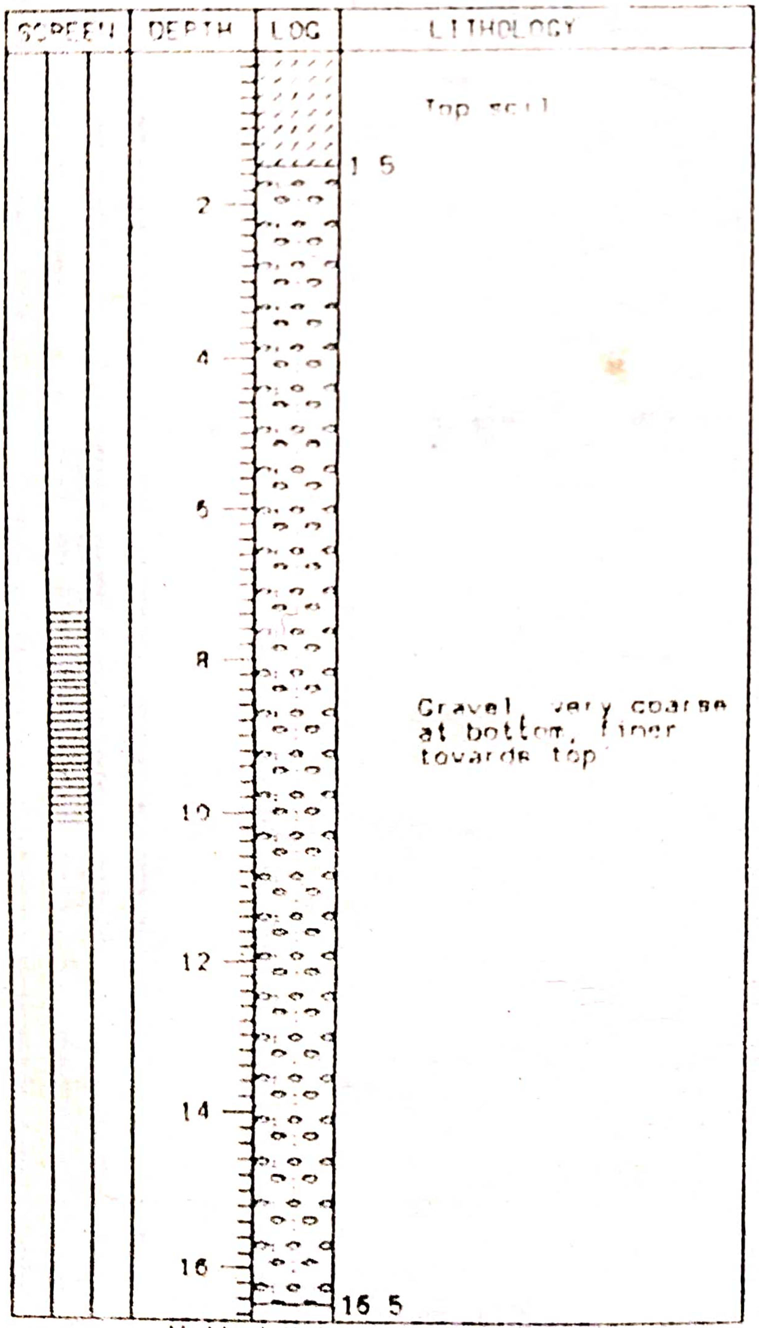
United Nations GW Software

Date: 25 4 90
Capacity: 20 l/s
Duration: 240 min
Transmiss.: 14138 m2/day
Method: Jacob
SWL: -3 65 m
DWL: -5 41 m

B-2. Well log of UN 2.

Well No UN 3	Location: BHAVANIPUR
Elevation 86 7	X = 344950 Y = 2976400
Method of Drilling	Manual
Drilling Dates	2 4 1990 - 5 4 1990
Total Depth	16 46
Comments	Well size 4" Screen position 7 35 - 10 1 m Screen type Johnson M P 0 9 m Drilling stopped due to hard formation

WELL LOG



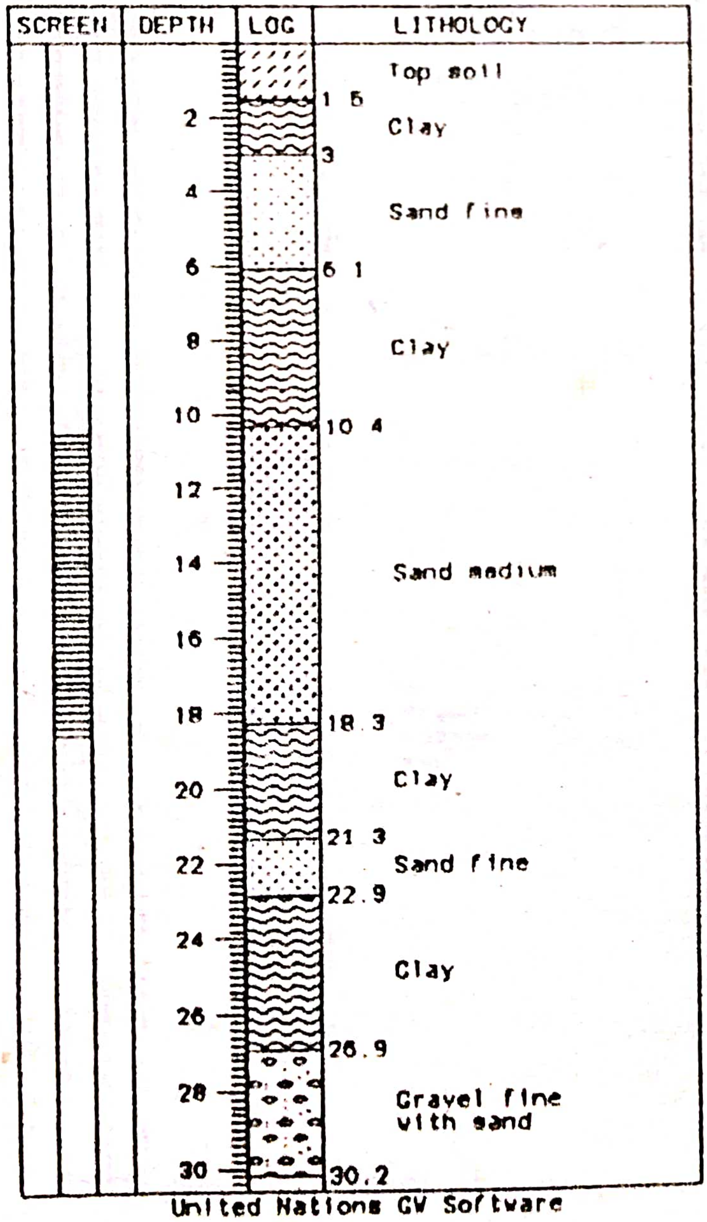
United Nations GW Software

Date 18 4 1990
Capacity: 25 l/s
Duration 240 min
SWL -3.42 m
DWL -6.86 m

B-3. Well log of UN 3.

Well No. UN 4	Location: AURAHI (CHAINPUR)
Elevation: 87.9	X = 350900 Y = 2974650
Method of Drilling: Manual	
Drilling Dates : 6.4.1990 - 10.4.1990	
Total Depth : 30.18	
Comments : Well size: 4" Screen position: 10.5 - 18.5 m Screen type: Johnson M.P. 0.5 m	

WELL LOG



United Nations GW Software

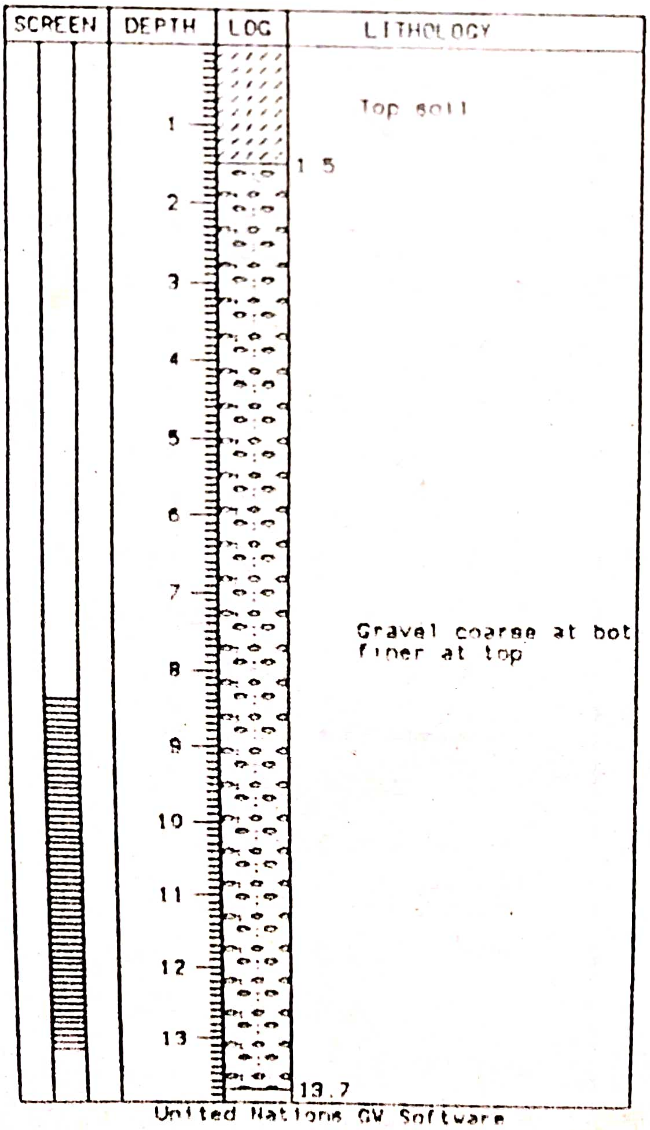
Date 15.4.1990
Capacity: 6.25 l/s
Duration: 120 min
SWL: -3.24 m
DWL: -8.15 m

B-4. Well log of UN 4.

APPENDIX B contd...

Well No UN 5	Location: SHANKARPUR
Elevation: 101 2	X = 348650 Y = 2991200
Method of Drilling: Rig	
Drilling Dates: 2 4 1990 - 6 4 1990	
Total Depth: 13 72	
Comments: Well size: 4" Screen position 8 4 - 13 14 m Screen type Slotted M P 0 45 m Hard formation mud flushed into gravel	

W E L L   L O G

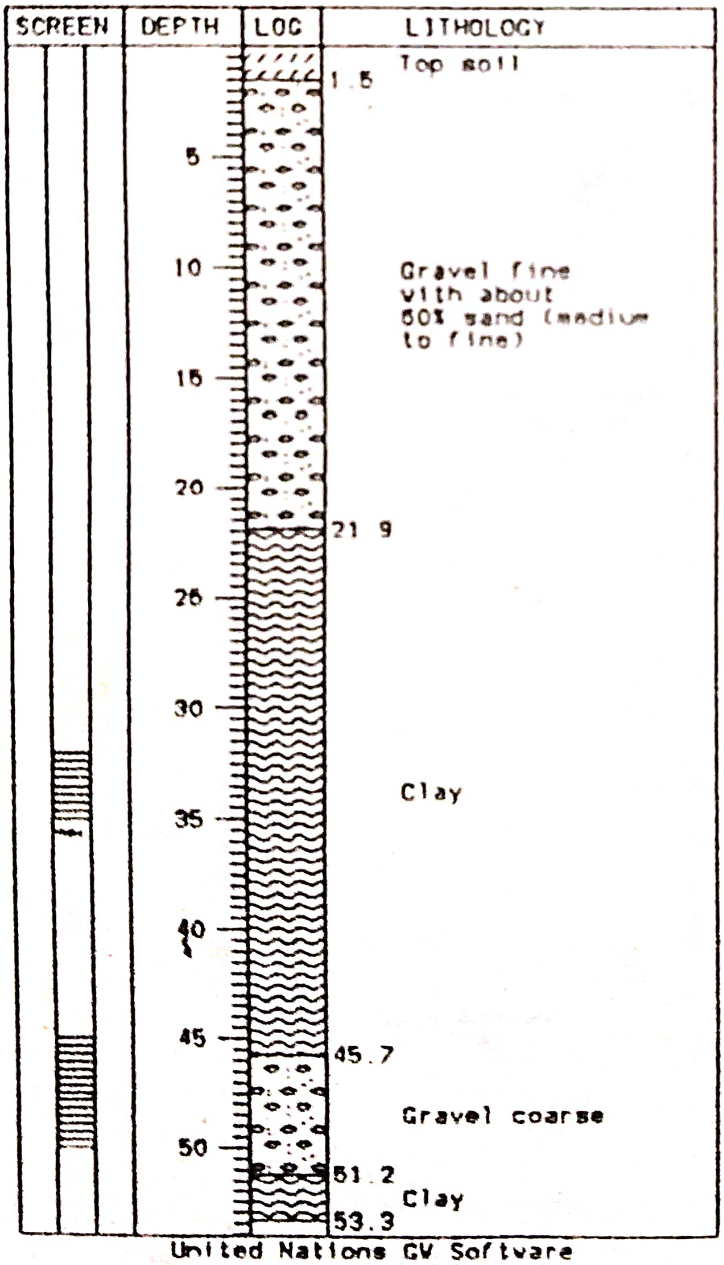


Date: 7 4 1990
Capacity: ?
Duration: 60 min.
SWL: -7 10 m
DWL: -8 58 m

B-5. Well log of UN 5.

Well No UN 6	Location: HARIPUR
Elevation: 114 5	X = 359600 Y = 2989600
Method of Drilling: Rig	
Drilling Dates : 8 4 1990 - 9 4 1990	
Total Depth : 53 34	
Comments : Well size: 4" Screen position: 32 35 - 45 5 m Screen type Slotted H P: 0 5 m	

W E L L   L O G

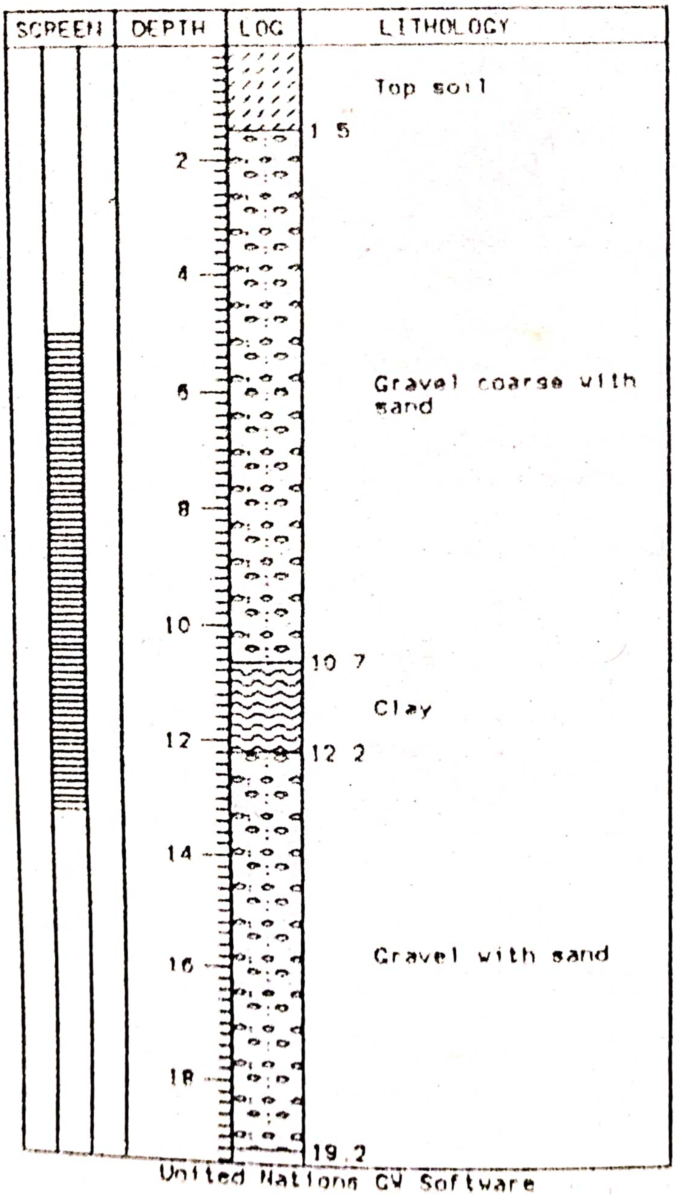


Date 18 4 1990
Capacity: 2 l/s
Duration: 240 min
SVL : -7 07 m
DVL -7 64 m

B-6. Well log of UN 6.

Well No UN 7	Location: SHISHAUT
Elevation 77 1	X = 345460 Y = 2971350
Method of Drilling	
Drilling Dates 7 4 1990 - 11 4 1990	
Total Depth 19 20	
Comments	Well size 4" Screen position 5 0 - 13 25 m Screen type Johnson M P 0 50 m Hard formation encountered

W E L L   L O G



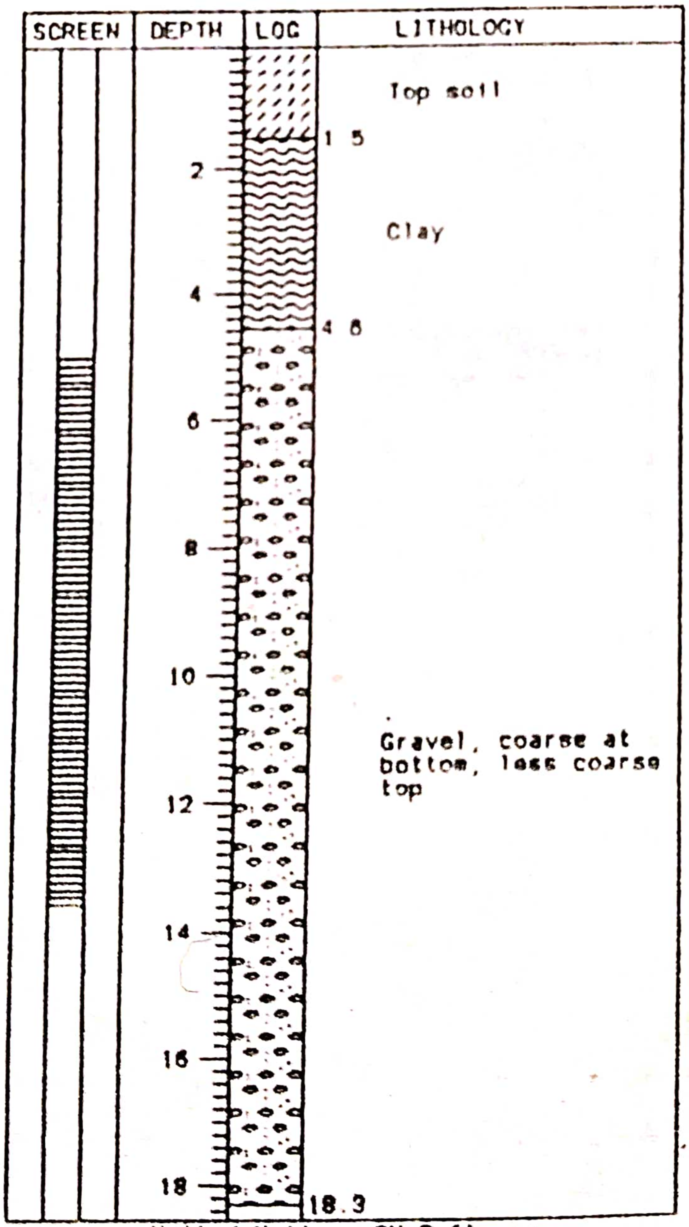
United Nations GW Software

Date: 23 4 1990
Capacity: 25 l/s
Duration: 240 min
SWL: -2.01 m
DWL: -5.25 m

B-7. Well log of UN 7.

Well No UN 8	Location: BAIRIYA
Elevation: 77.8	X = 338260 Y = 2970550
Method of Drilling: Manual	
Drilling Dates : 14.4.1990 - 16.4.1990	
Total Depth : 18.29	
Comments : Well size: 4" Screen position 5.0 - 13,57 m Screen type: Johnson M. P.: 0.50 m	

WELL LOG



United Nations GV Software

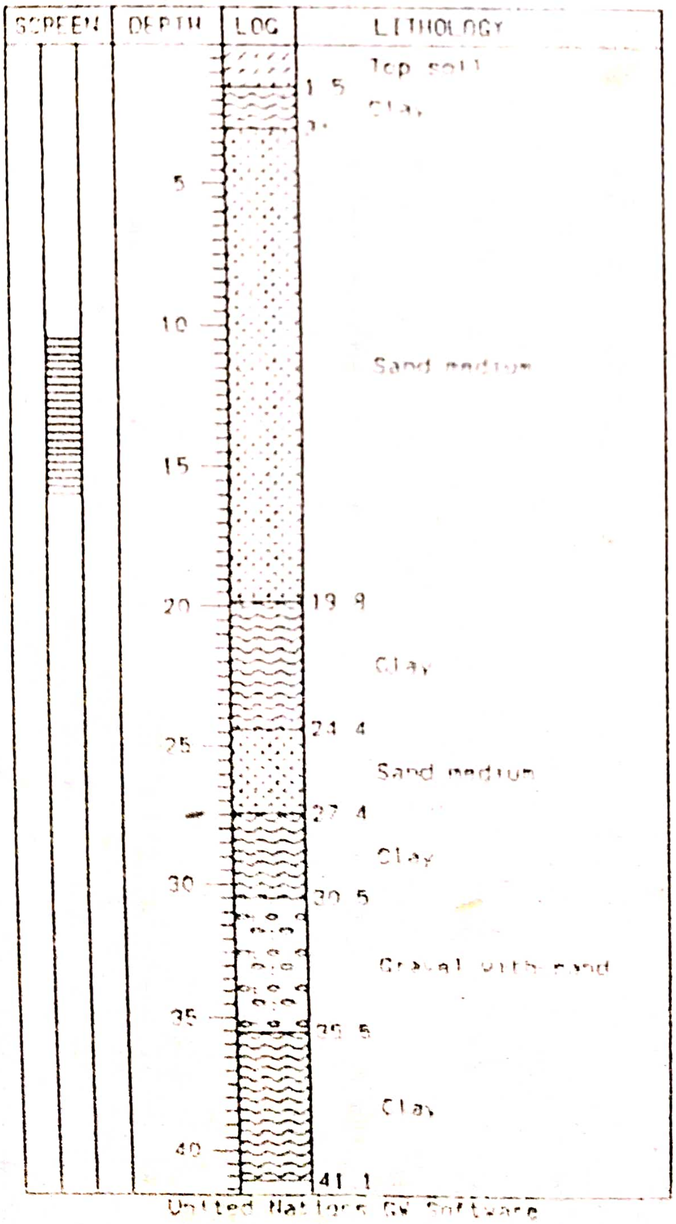
Date: 30.4.1990
Capacity: 25 l/s
Duration: 120 min
SWL: -2.03 m
DWL: -4.77 m

B-8. Well log of UN 8.

APPENDIX B contd...

Well No UN 9	Location BALARA
Elevation 72 7	X = 338200 Y = 2962200
Method of Drilling Manual	
Drilling Dates 18 4 1990 - 23 4 1990	
Total Depth 41 14	
Comments Well size 4" Screen position 10 5 - 16 01 m Screen type Johnson M P 0 45 m	

W E L L   L O G

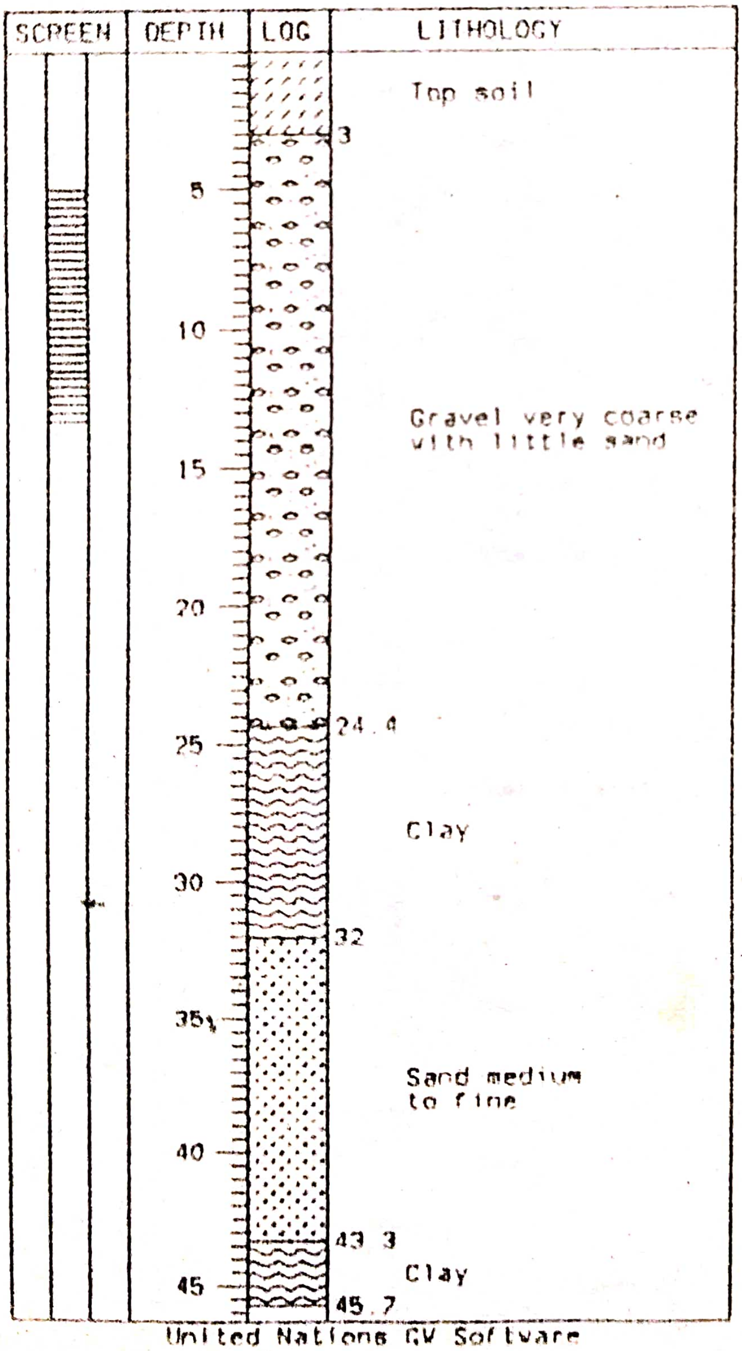


Date 6 5 1990
Capacity 27 5 l/s
Duration 210 minutes
SWL 3 01 m
DWL -5 92 m

B-9. Well log of UN 9.

Well No UN 10	Location MADHUBAN
Elevation: 75 3	X = 346990 Y = 2964970
Method of Drilling: Manual	
Drilling Dates : 24 4 1990 - 26 4 1990	
Total Depth : 45.73	
Comments : Well size 4" Screen position: 5 0 -13 25 m Screen type. Johnson M P 0 50 m	

W E L L   L O G

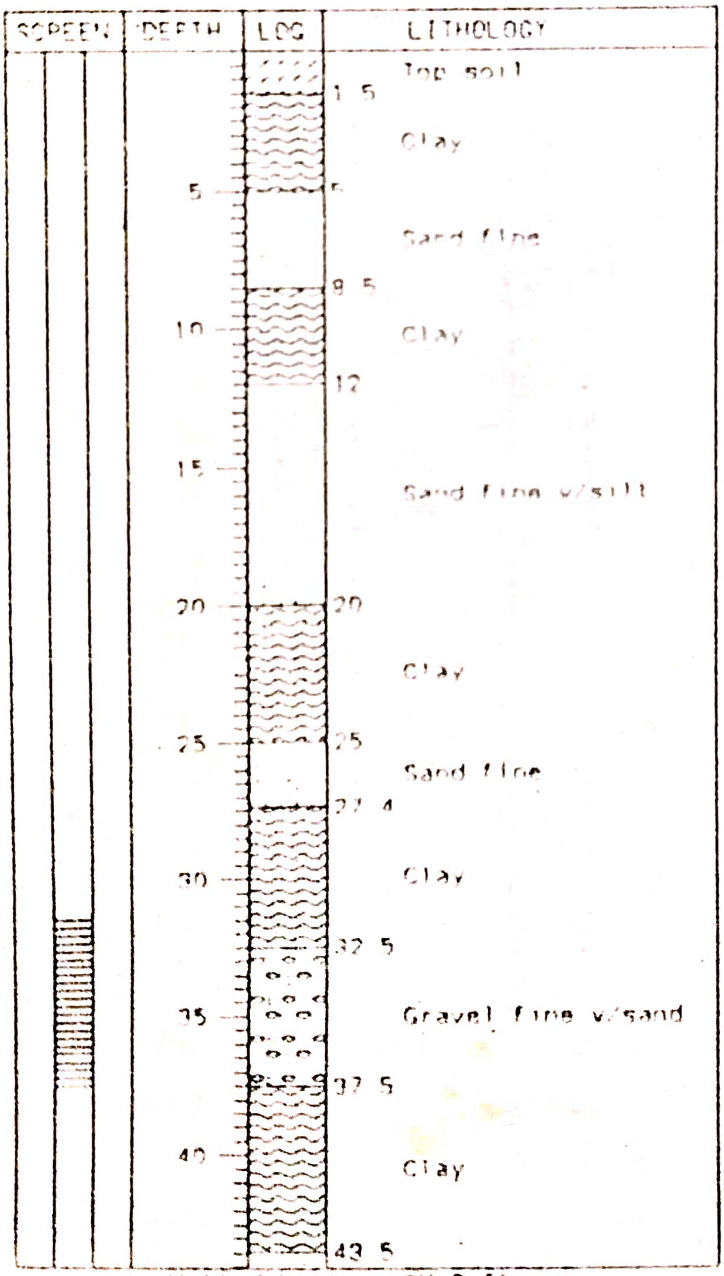


Date 9 May 1990
Capacity 16 7 l/s
Duration 240 min
SWL -2 95 m
DWL -5 94 m

B-10. Well log of UN 10.

Well No UN 11	Location NAWALPUR
Elevation 139 1	x = 360180 Y = 2994130
Method of Drilling Rig	
Drilling Dates 16 4 1990 - 18 4 1990	
Total Depth 43 46	
Comments Well size 6"/4" Screen position 31 4 - 37 4 m Screen type Slotted M P 0 40 m	

W E L L   L O G



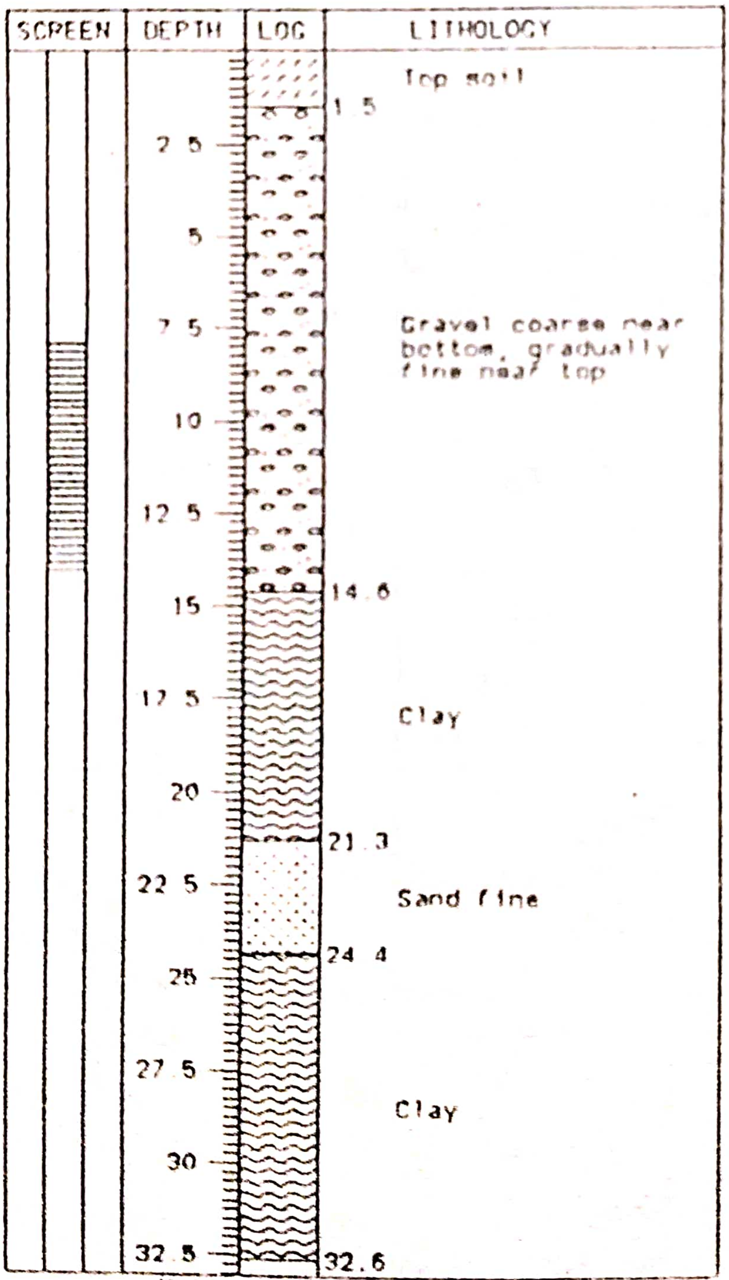
SWL -16 58 m

United Nations GW Software

B-11. Well log of UN 11.

Well No UN 12	Location: BAILBAS
Elevation: 134 6	x = 363000 Y = 2987400
Method of Drilling: Rig	
Drilling Dates 23 4 1990 - 25 4 1990	
Total Depth : 32 61	
Comments Well size 4" Screen position 7 9 - 14 m Screen type Slotted M P 0 40 m	

WELL LOG

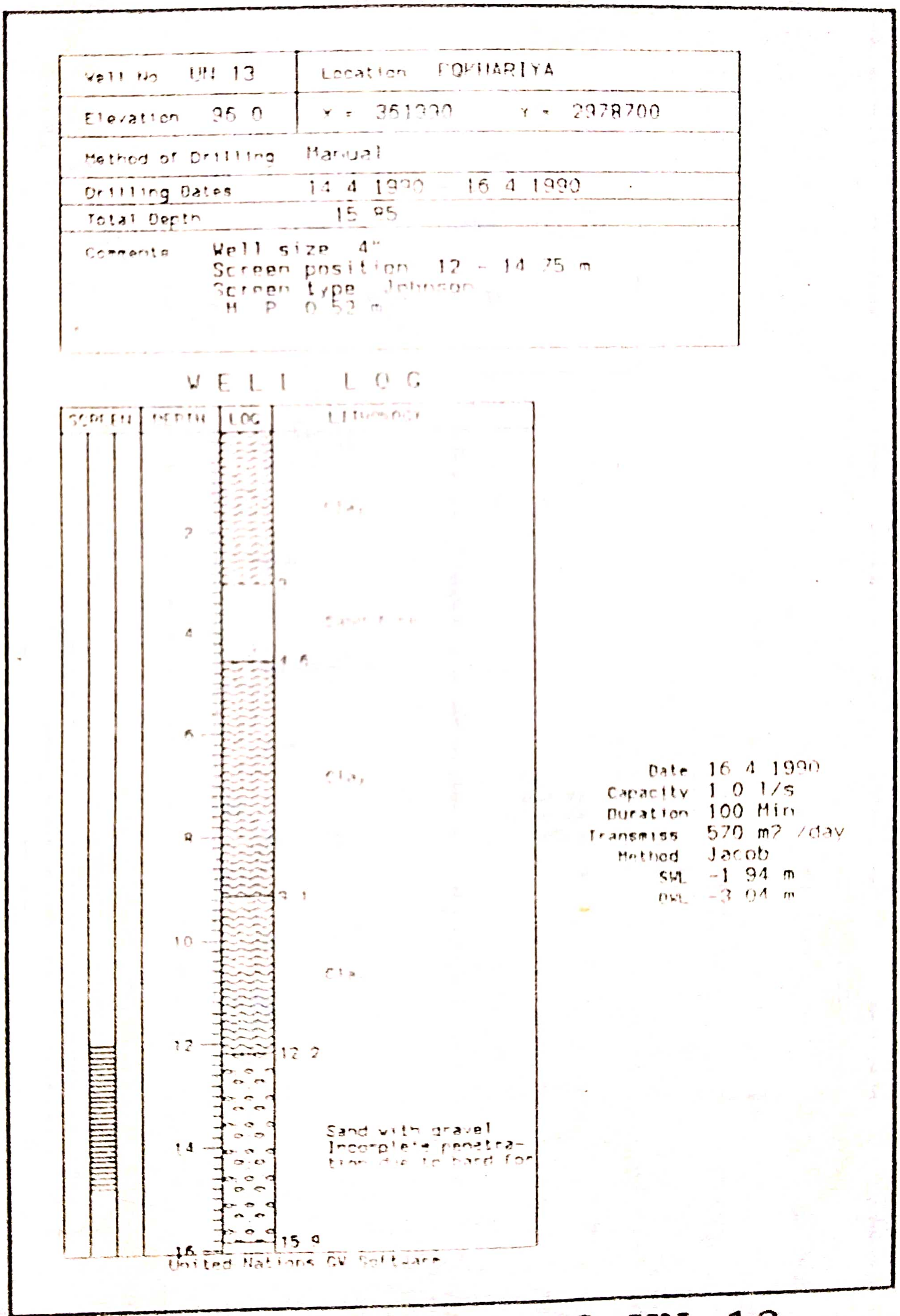


United Nations GW Software

Date 1 5 1990
Capacity: 12 l/s
Duration: 150 min
Transmiss : 1396 m2/day
Method : Theis
SWL -2 78 m
DWL -7 24 m

B-12. Well log of UN 12.

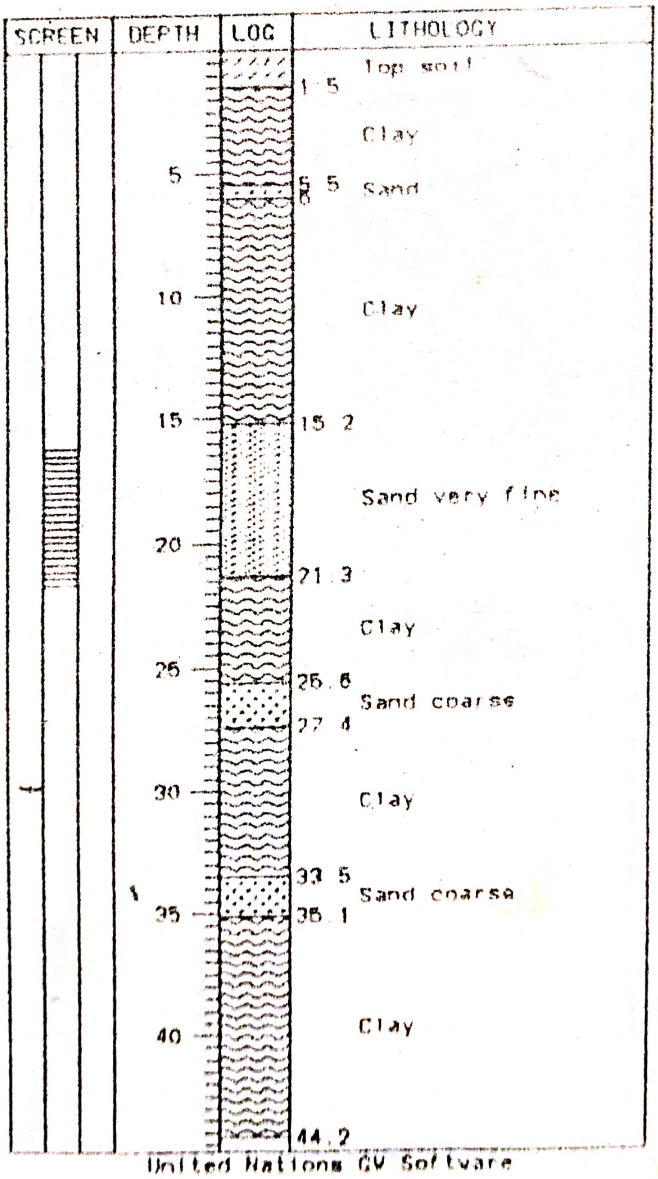
APPENDIX B contd...



B-13. Well log of UN 13.

Well No UN 14	Location MALANGAWA
Elevation 83 1	X = 357150 Y = 2971200
Method of Drilling	Manual
Drilling Dates	6 4 1990 - 12 4 1990
Total Depth	44 20
Comments	Well size 4" Screen position 16 1 - 21 6 m Screen type Johnson M P 0 40 m

W E L L L O G

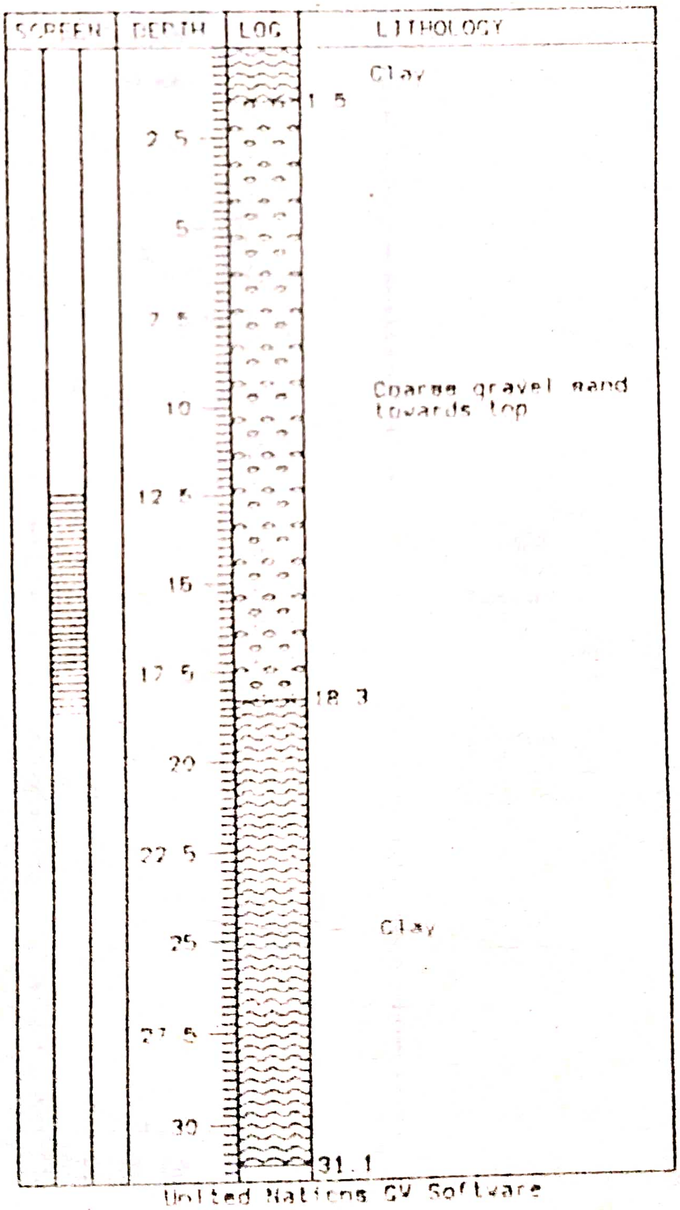


Date 20 4 1990
Capacity 1 5 l/s
Duration 180 min
Transmiss 76m2/day
Method Theis
SWL -3 18 m
DWL -6 61 m

B-14. Well log of UN 14.

Well No UN 15	Location: SRINAGAR
Elevation 132 6	x = 373000 y = 2985000
Method of Drilling RIG	
Drilling Dates 27 4 90 - 1 5 90	
Total Depth 31 08	
Comments Well size 4" Screen position 12 4 - 18 5 m Screen type Slotted pipe M P 0 48 m S W L 0 48 m	

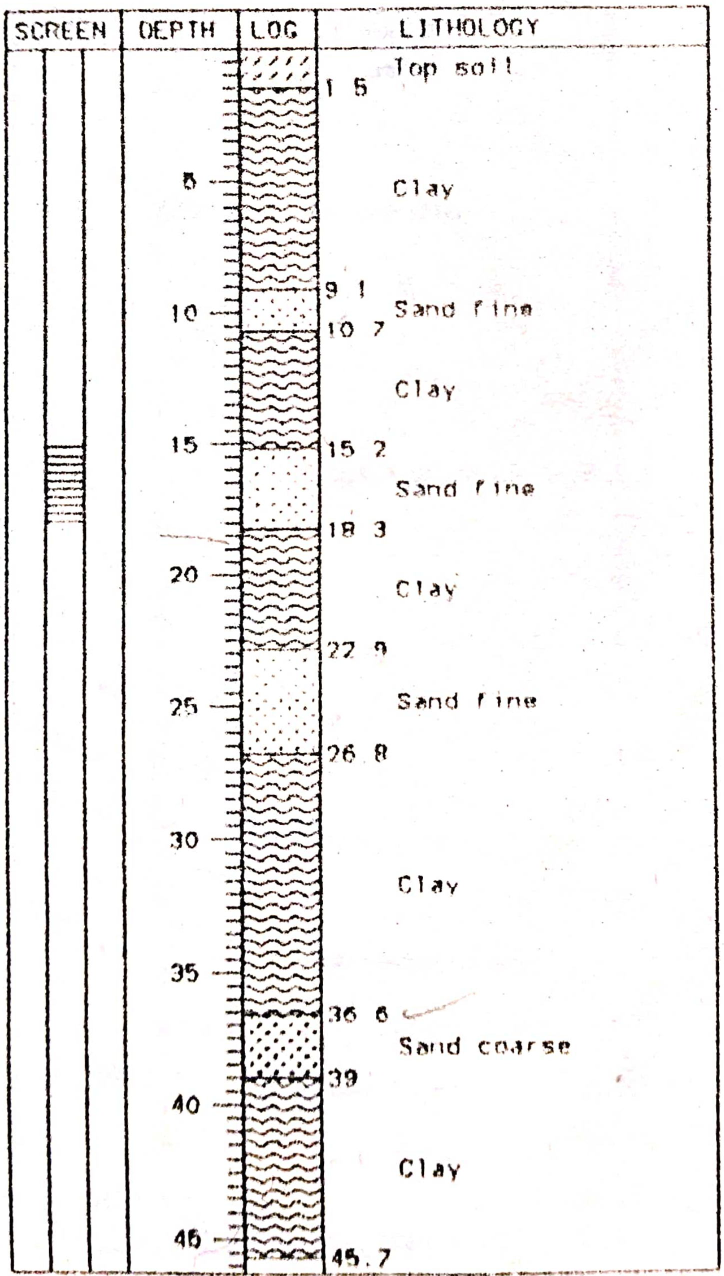
W E L L   L O G



B-15. Well log of UN 15.

Well No UN 16	Location: JINGARAWA
Elevation: 90 3	X = 368200 Y = 2975400
Method of Drilling: Manual	
Drilling Dates 23 4 1990 - 26 4 1990	
Total Depth : 45 70	
Comments : Well Size: 4" Screen position: 15 07 - 17 92 m Screen type Johnson M P 0 5m	

W E L L L O G



United Nations GW Software

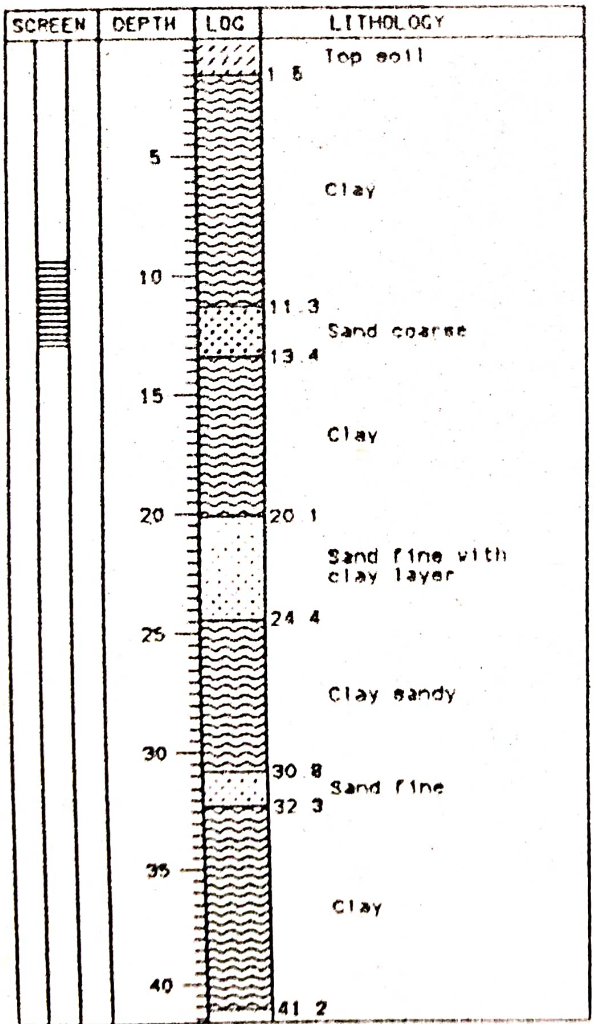
Date 13 5 1990
Capacity 1 5 l/s
Duration 120 min
Transmiss . 54 m2/day
Method Theis
SWL -3 18 m
DWL -8 15 m

B-16. Well log of UN 16.

APPENDIX B contd...

Well No UN 17	Location BASANTPUR
Elevation: 104.8	X = 369900 Y = 2978260
Method of Drilling Manual	
Drilling Dates 17.4.1990 - 22.4.1990	
Total Depth : 41.15	
Comments Well Size: 4" Screen position. 9.36 - 12.91 m Screen type: Johnson M.P: 0.4m	

WELL LOG



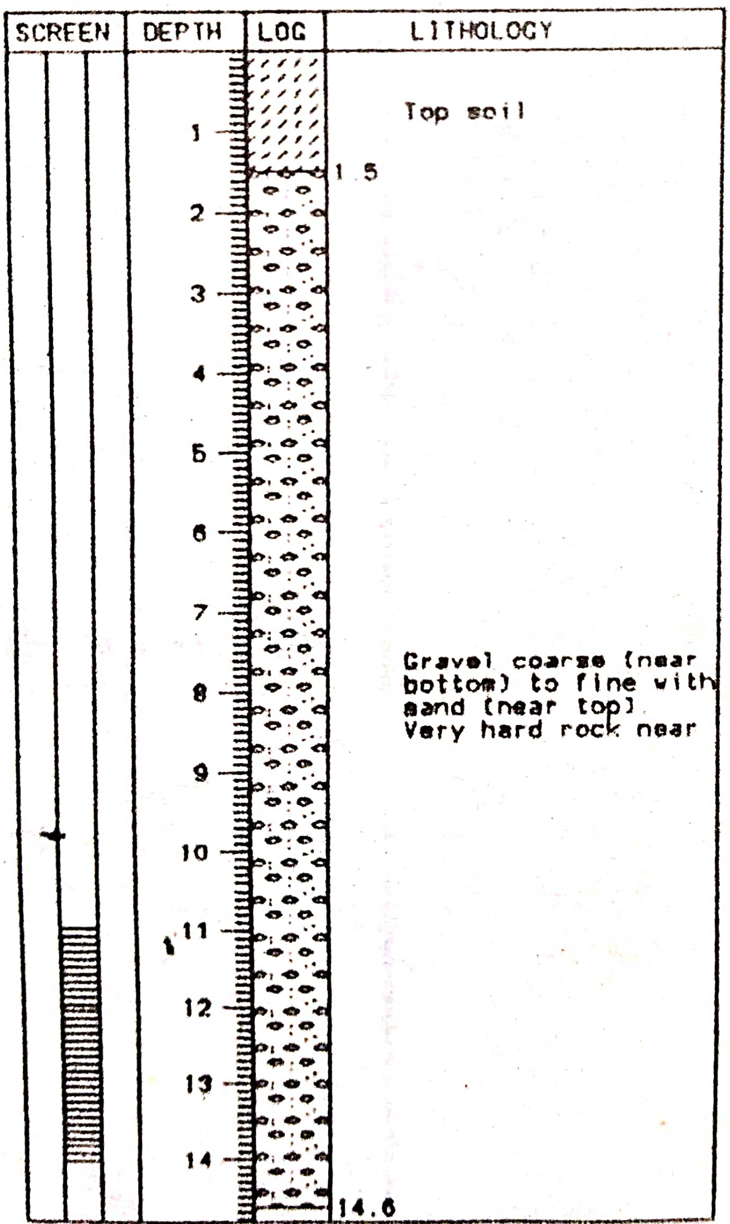
United Nations GV Software

Date: 3.5.1990
Capacity: 1.03 l/s
Duration: 120 min
Transmiss.: 79m2/day (obs. well)
Method : Theis
SWL: -2.35 m
DWL: -6.65 m

B-17. Well log of UN 17.

Well No. UN 18	Location: LALBANDI
Elevation: 148.8	X = 366500 Y = 2991720
Method of Drilling: Rig	
Drilling Dates : 8.5.1990 - 12.5.1990	
Total Depth : 14.63	
Comments : Well size: 4" Screen position: 10.97 - 14.04 m. Screen type: Slotted M. P. 0.45 m.	

WELL LOG



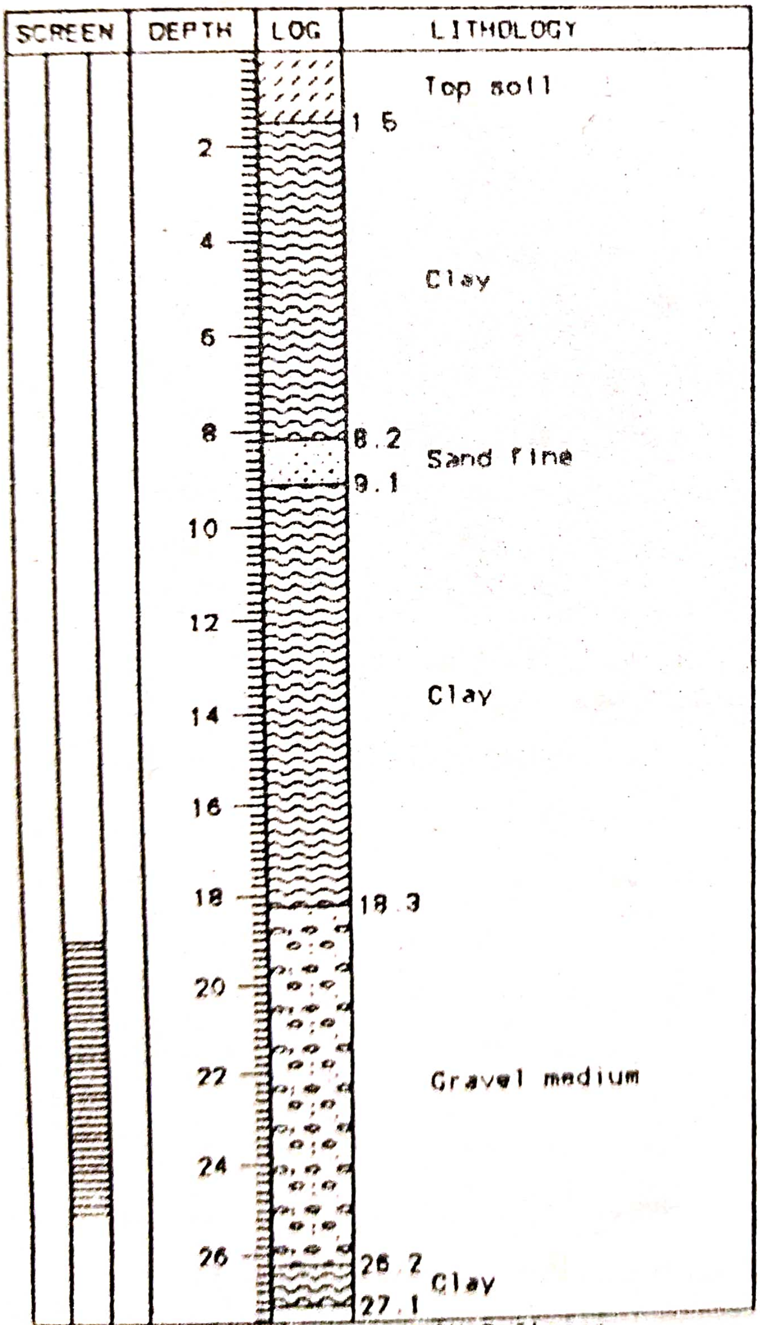
United Nations GW Software

SVL: -7.87 m

B-18. Well log of UN 18.

Well No. UN 19	Location. HARION
Elevation: 147 6	x145 356900 Y = 2996700
Method of Drilling. Rig	
Drilling Dates 17 5 1990 - 19 5 1990	
Total Depth 27 12	
Comments : Well size. 6"/4" Screen position 18 9 - 24 99 m Screen type Slotted M. P: 0.6 m	

WELL LOG



United Nations GW Software

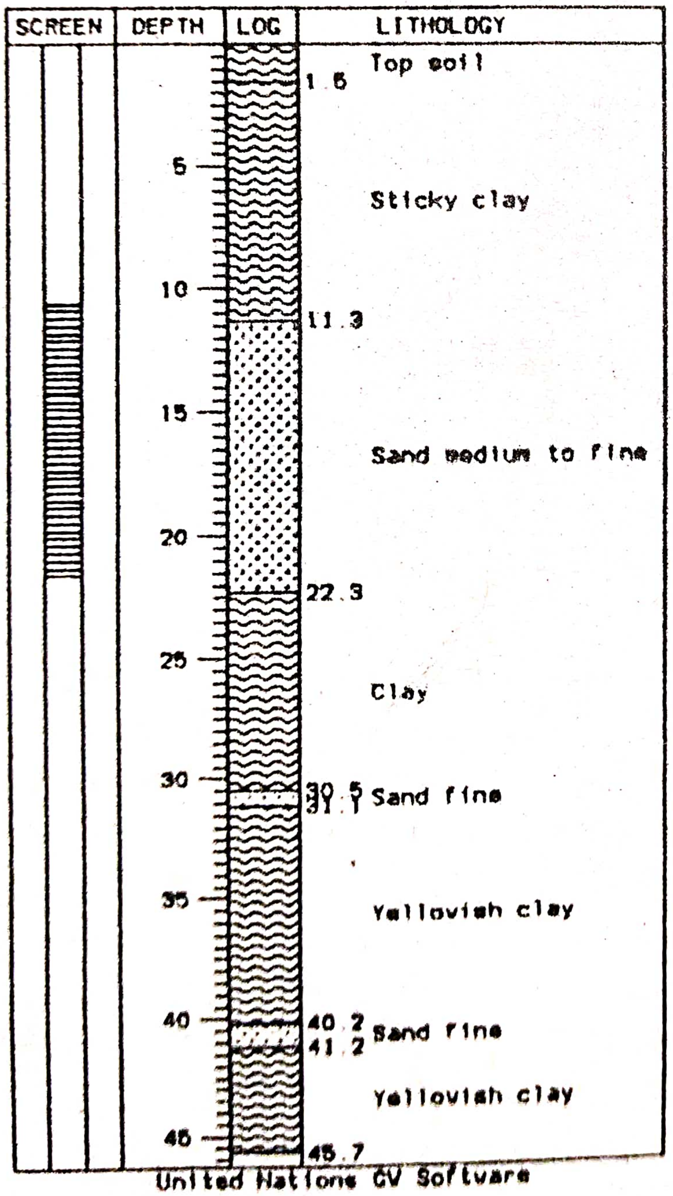
Date: 29.6.90
Capacity: 0.7 l/sec
Duration: 180 Min
Transmiss 14 m2/day
Method : Theis
SWL: -11.47 m.
DWL: -14.2 m.

Low transmissivity for the ava aquifer, well needs proper development and/ortreatment

B-19. Well log of UN 19.

Well No UN 20	Location: SIRSIYA
Elevation: 96.7	X - 356500 Y - 2981400
Method of Drilling: Mannual	
Drilling Dates : 1.7.90 - 4.7.90	
Total Depth : 45.70	
Comments : Well size: 4" Screen position : 10.6 - 21.6 m Screen type: Johnson H. P: 0.40 m	

W E L L   L O G



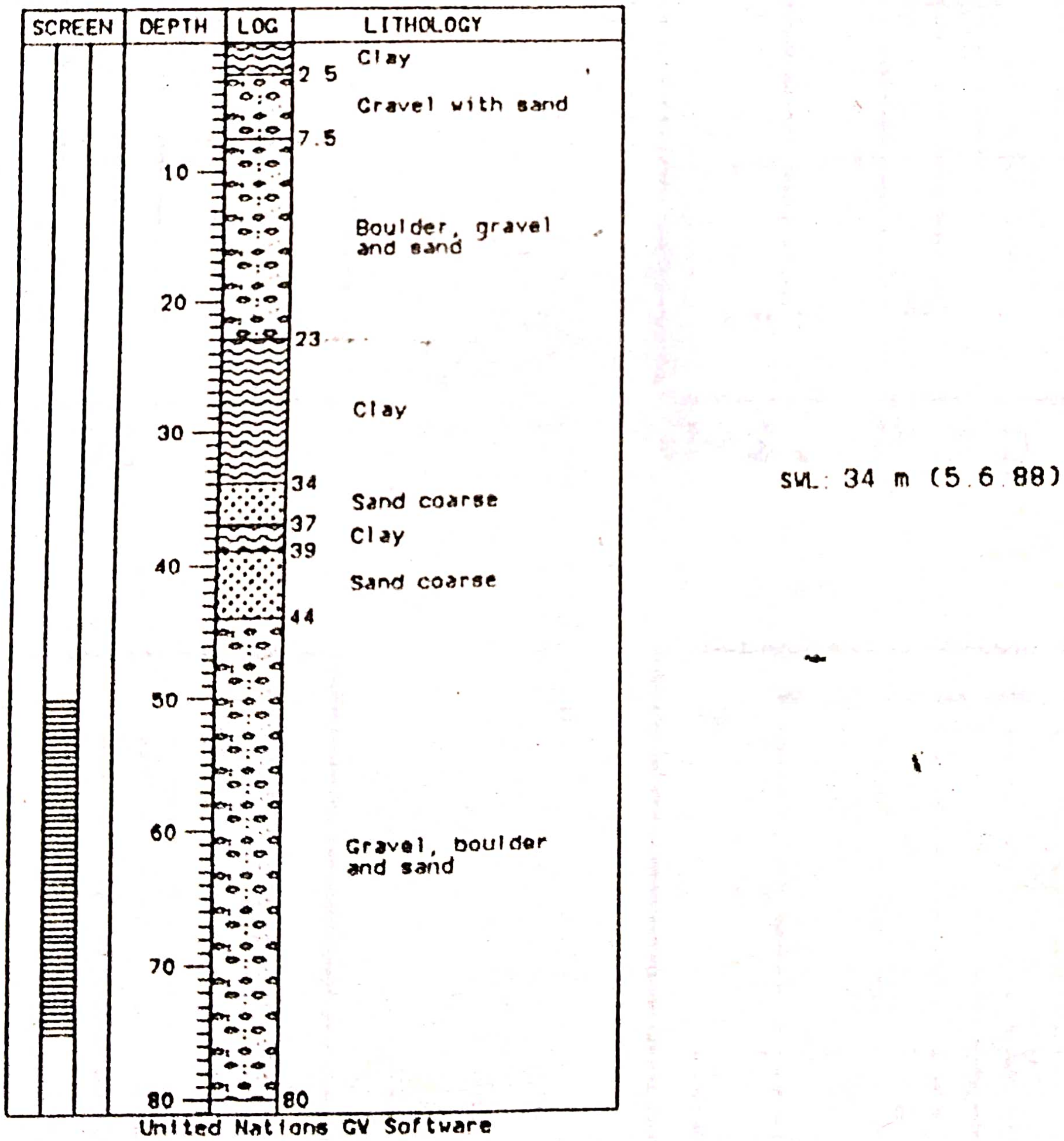
Date: 5.7.90 - 6.7.90
Capacity: 12 l/sec
Duration: 120 min.
Transmiss.: 2757 m2/day
Method : Jacob
SWL: -2.51m.
DWL: -8.05m

B-20. Well log of UN 20.

contd...

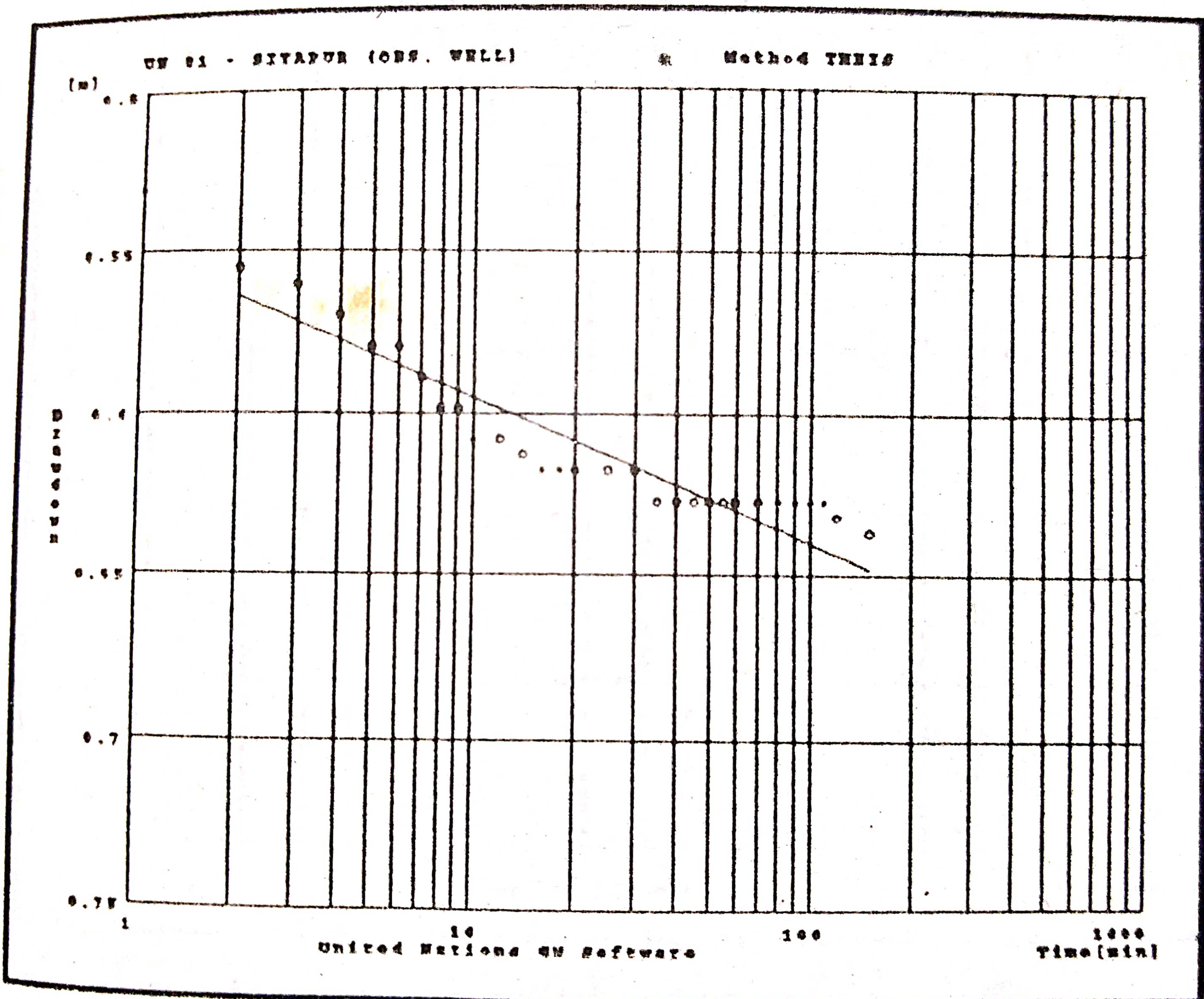
Well No. NC 2	Location: KARMAIYA
Elevation: 128	X = 351250 Y = 3002000
Method of Drilling: PERCUSSION RIG	
Drilling Dates : 10.11.85 - 09.01.86	
Total Depth : 80.00	
Comments : Well size: 8"/12". Screen Position: 50 - 75 m. Located in compound of Bagmati Irrigation Project	

WELL LOG

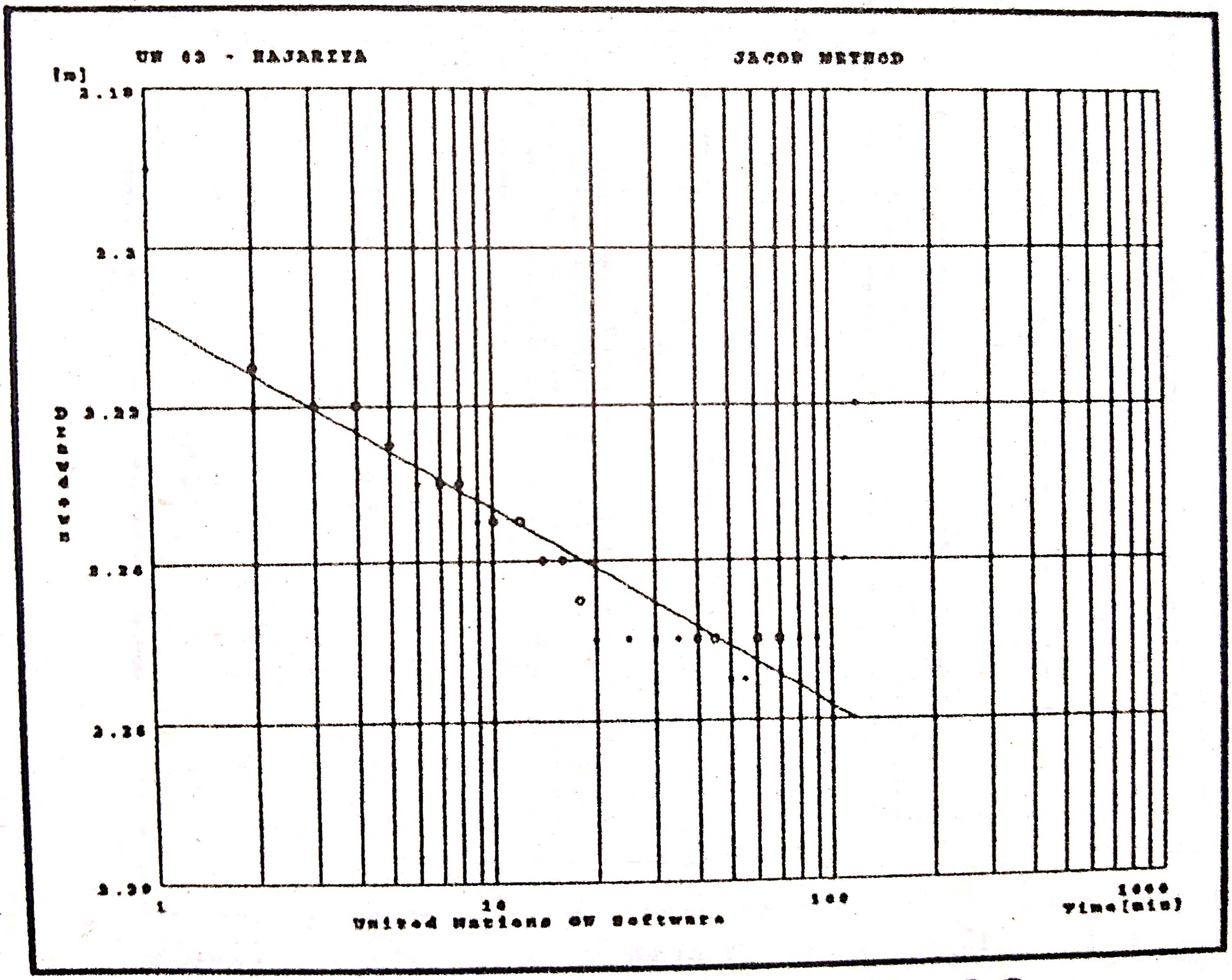


B-21. Well log of NC 2.

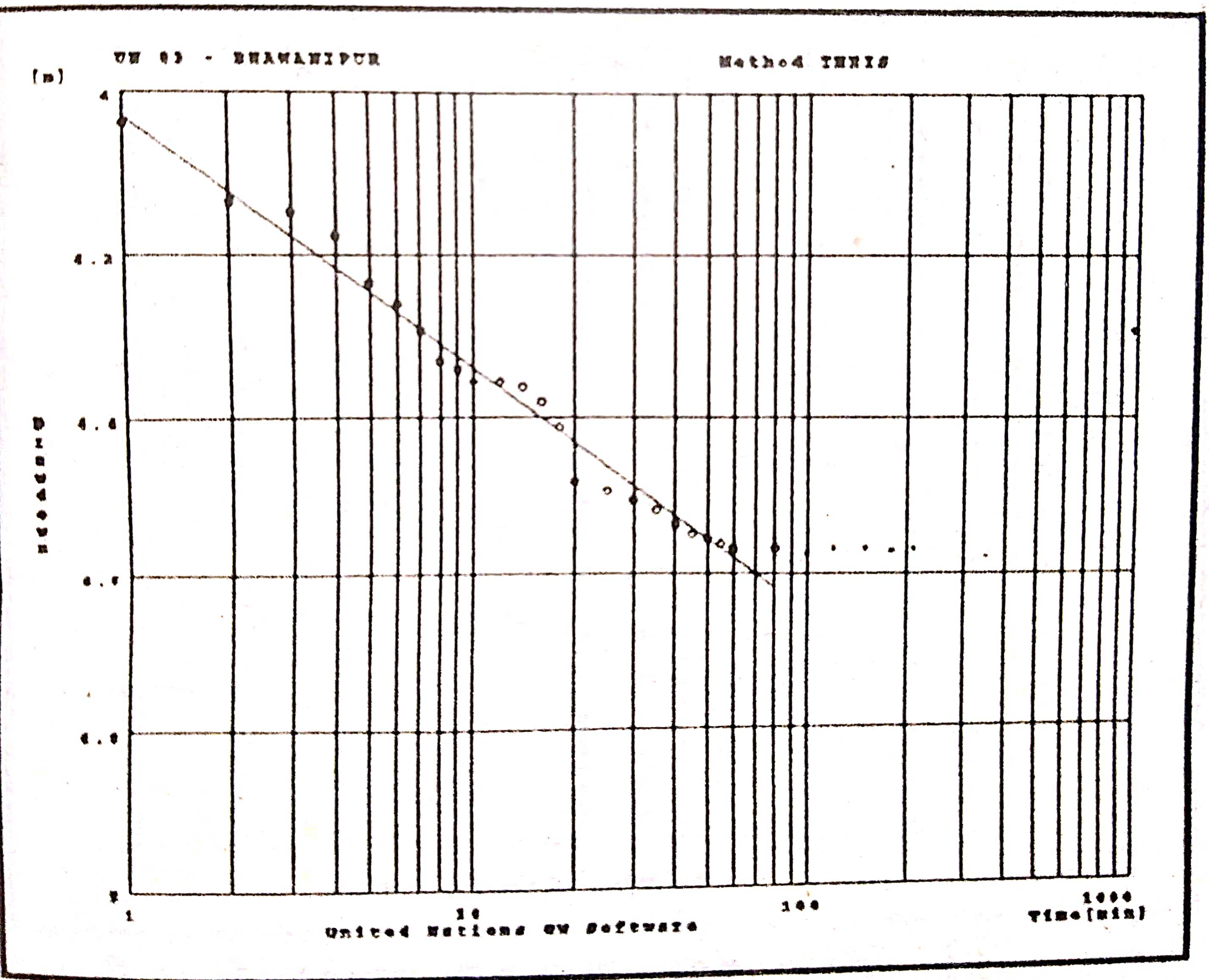
APPENDIX C
PUMPING TEST GRAPHS



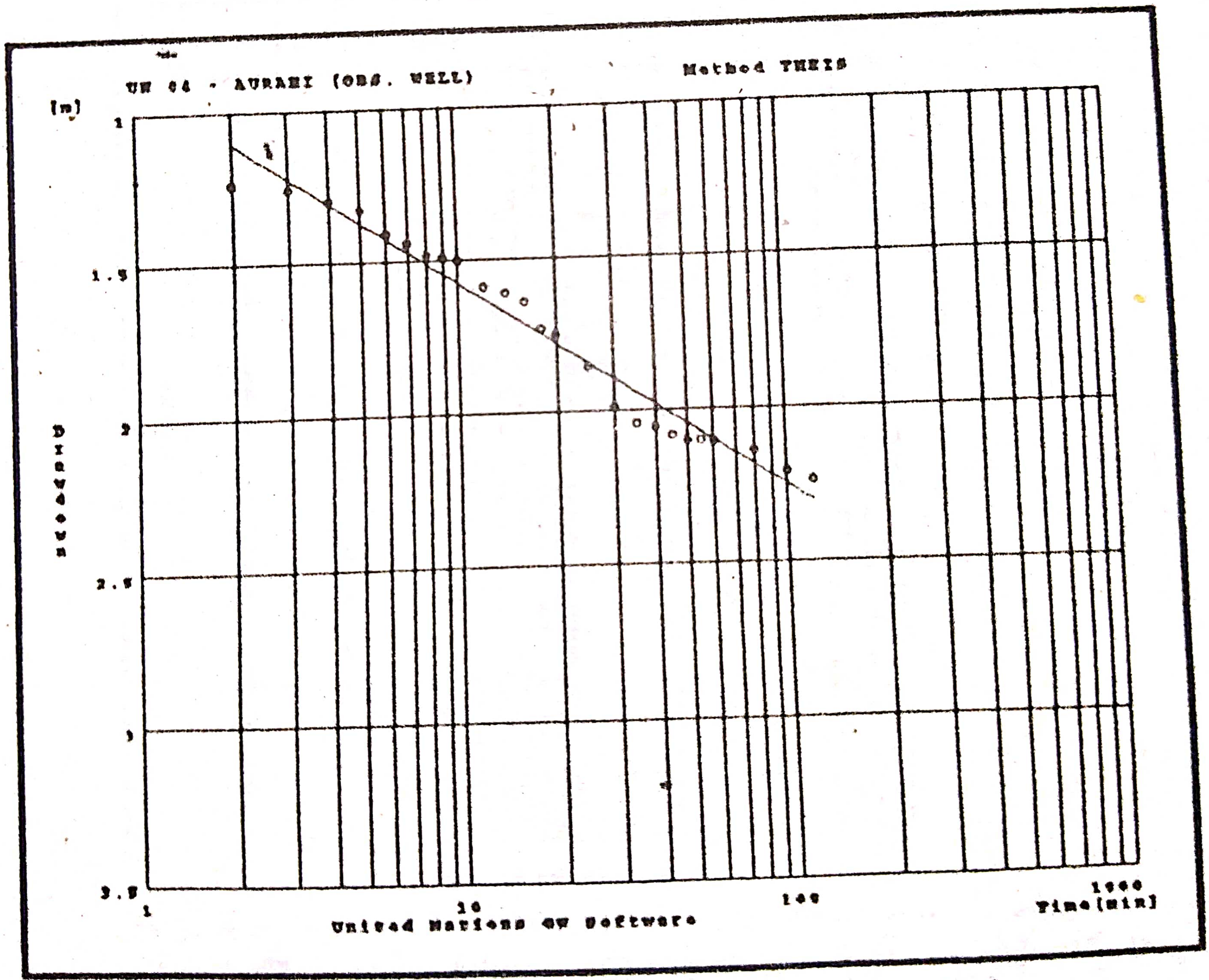
C-1. Pump test of UN 01.



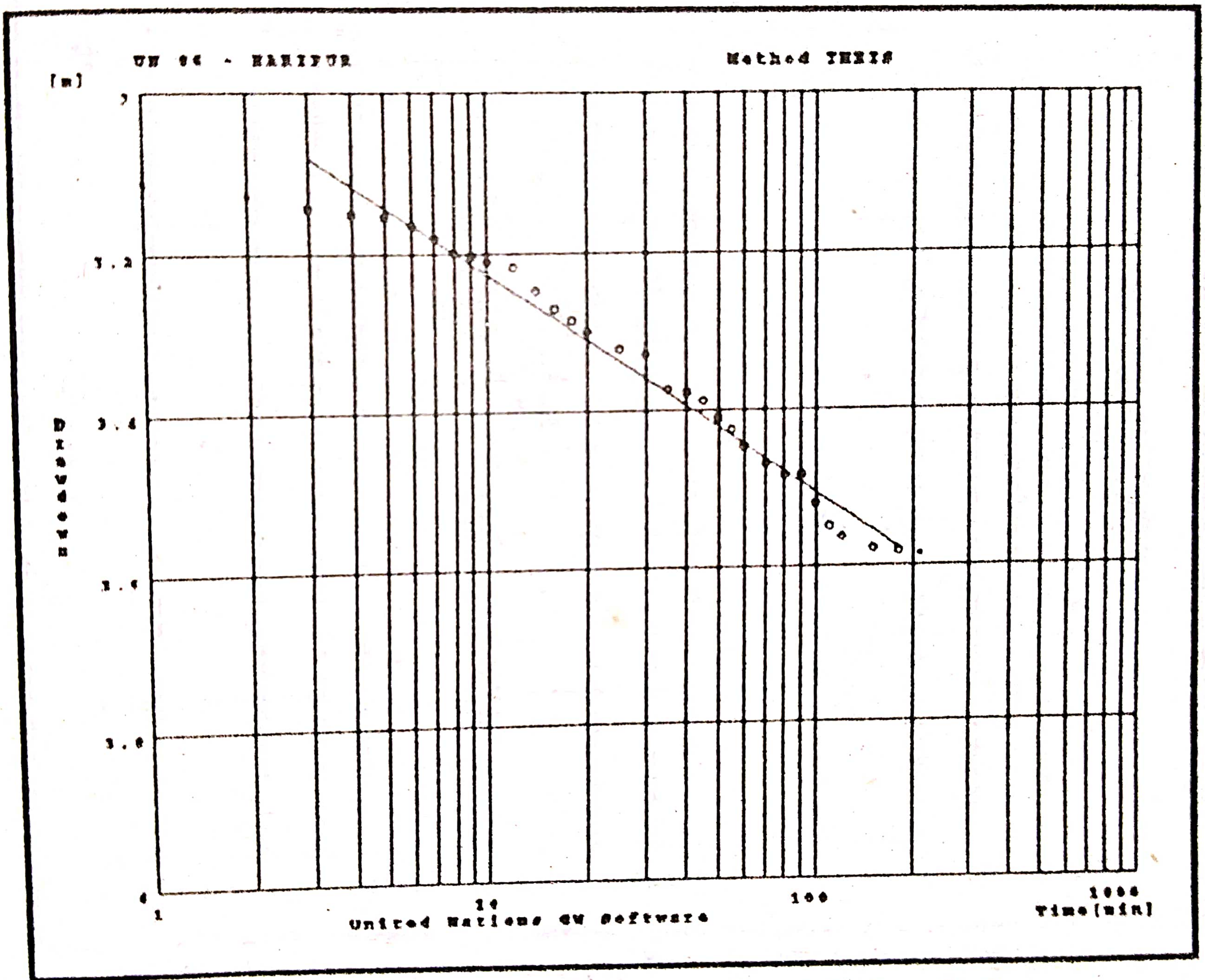
C-2. Pump test of UN 02



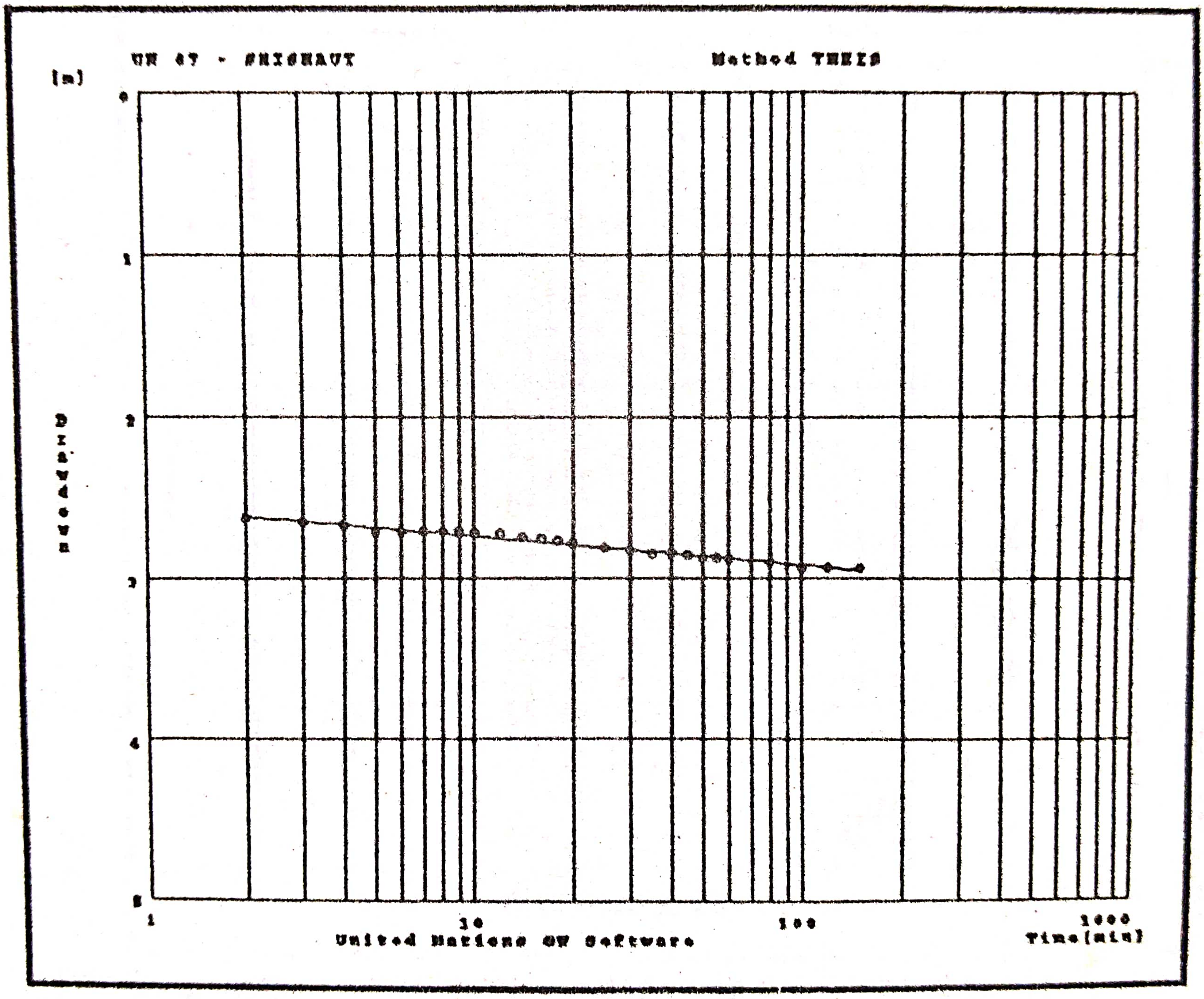
C-3. Pump test of UN 03.



C-4. Pump test of UN 04.

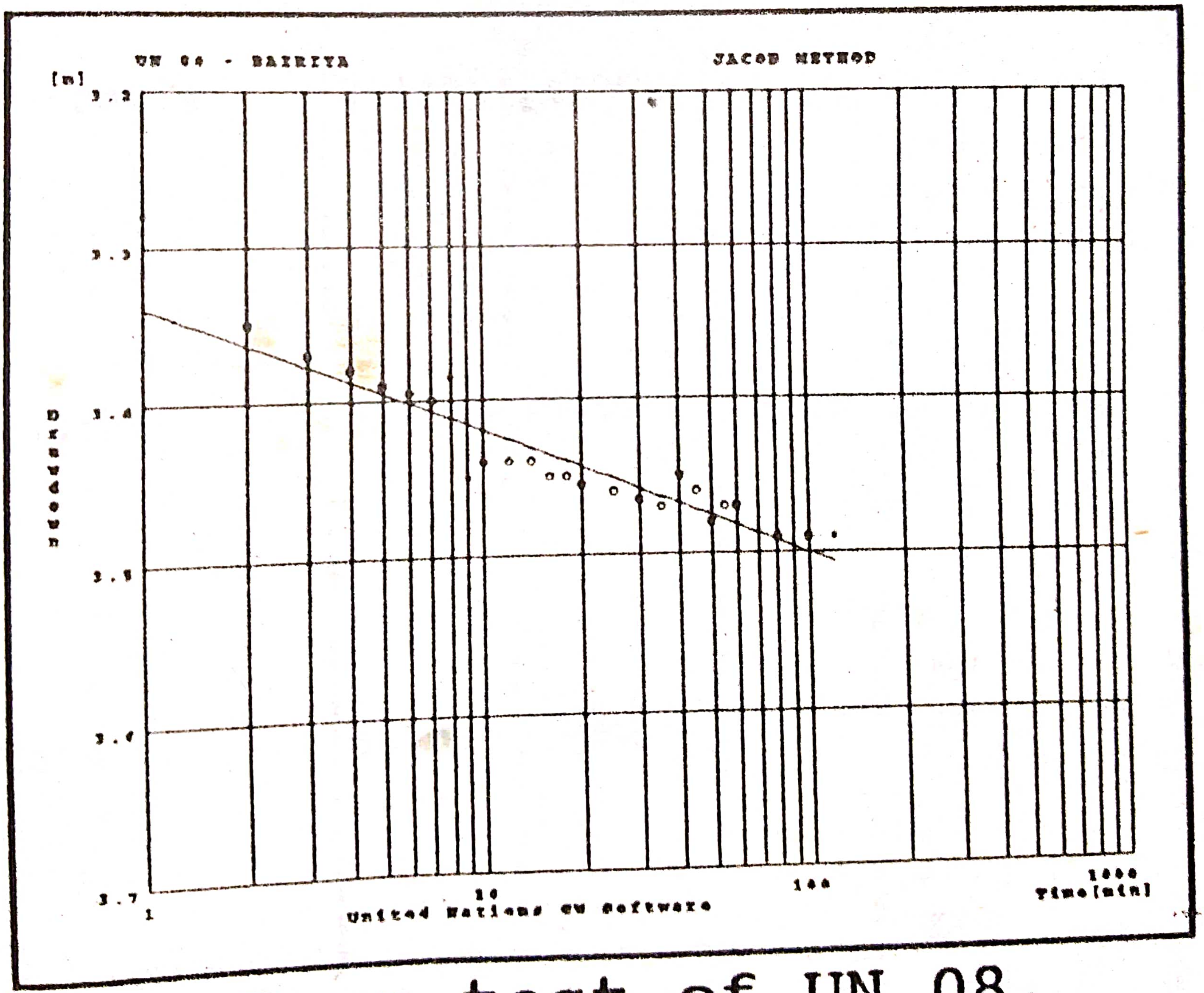


C-5. Pump test of UN 06.

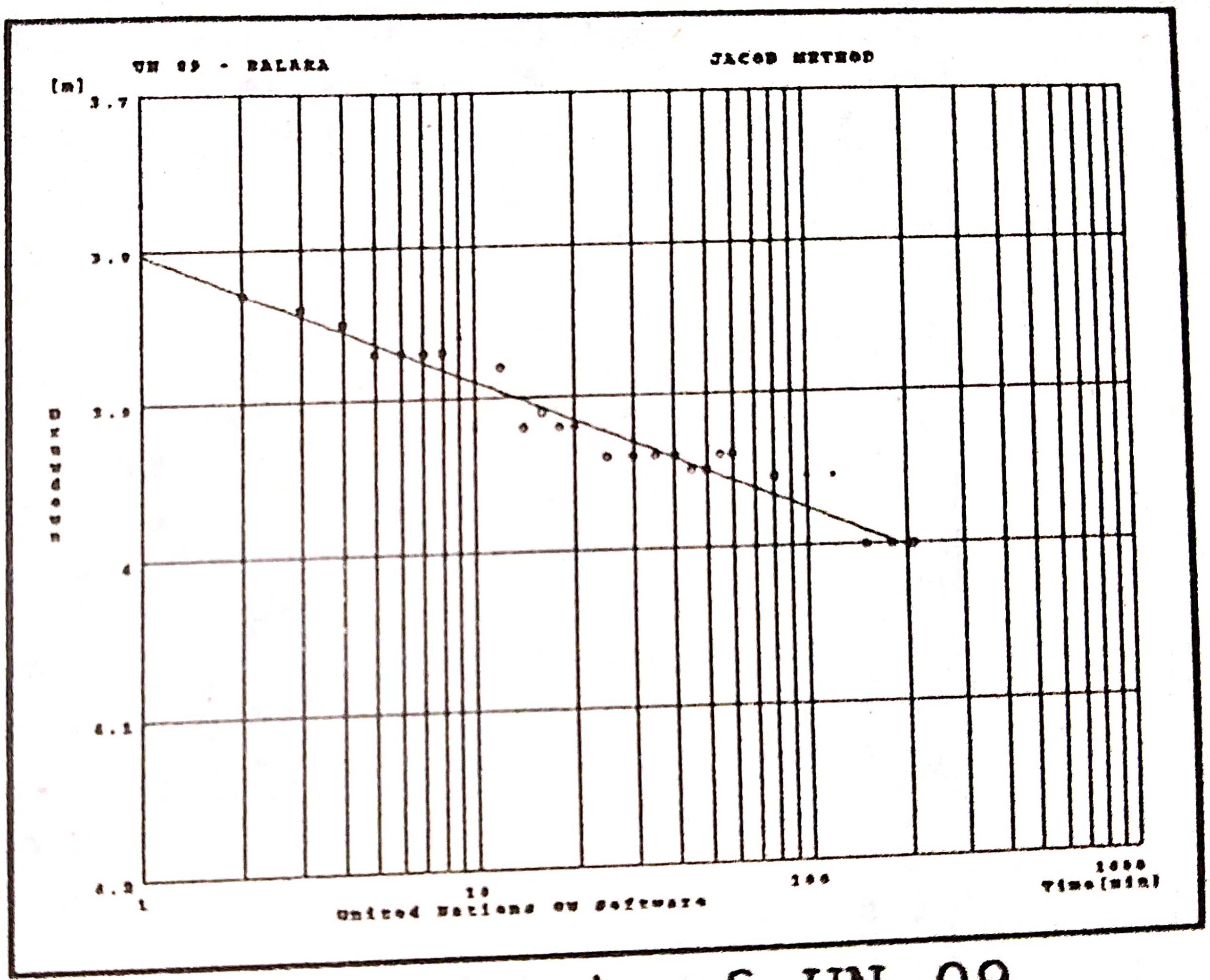


C-6. Pump test of UN 07.

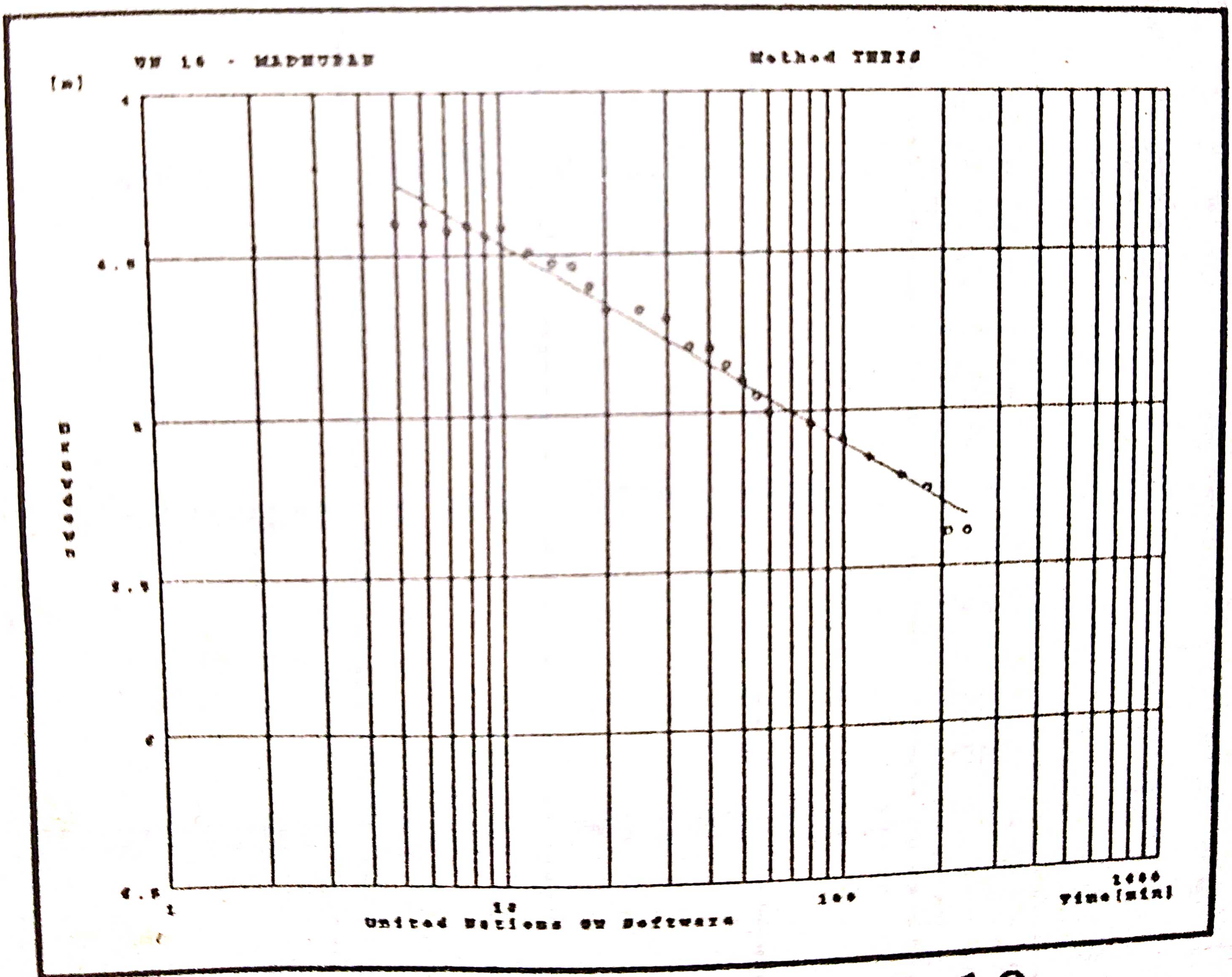
APPENDIX C contd...



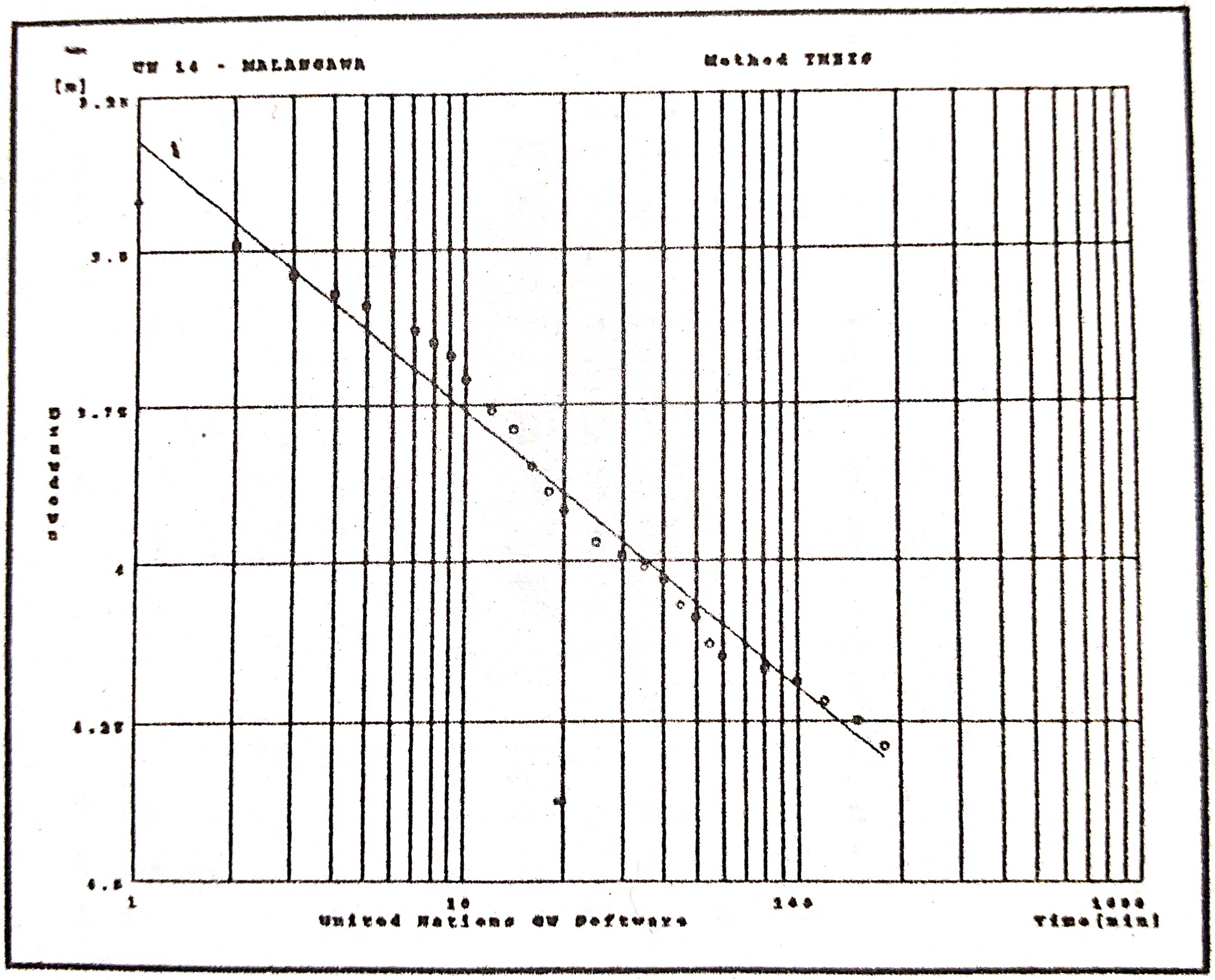
C-7. Pump test of UN 08.



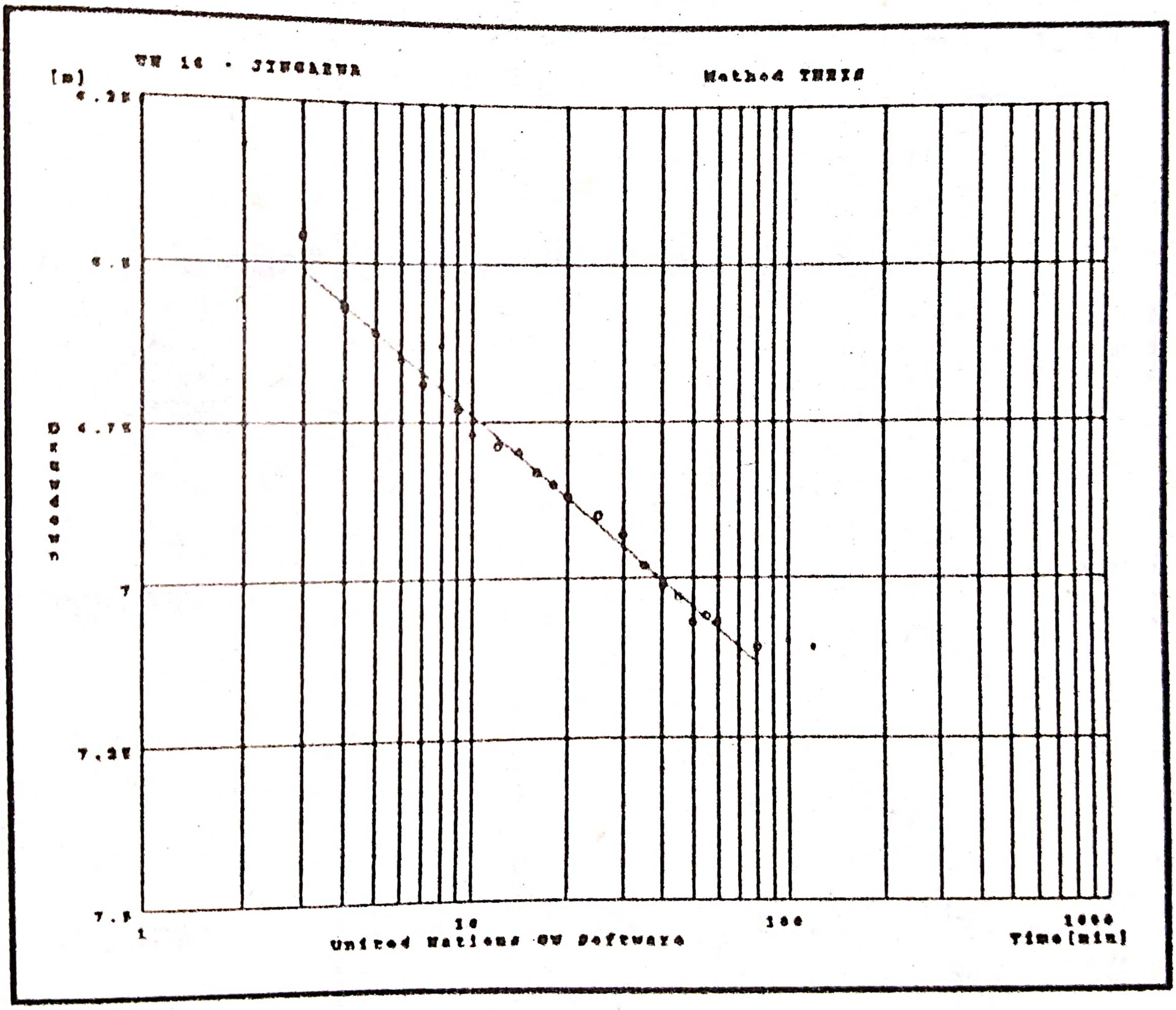
C-8. Pump test of UN 09.



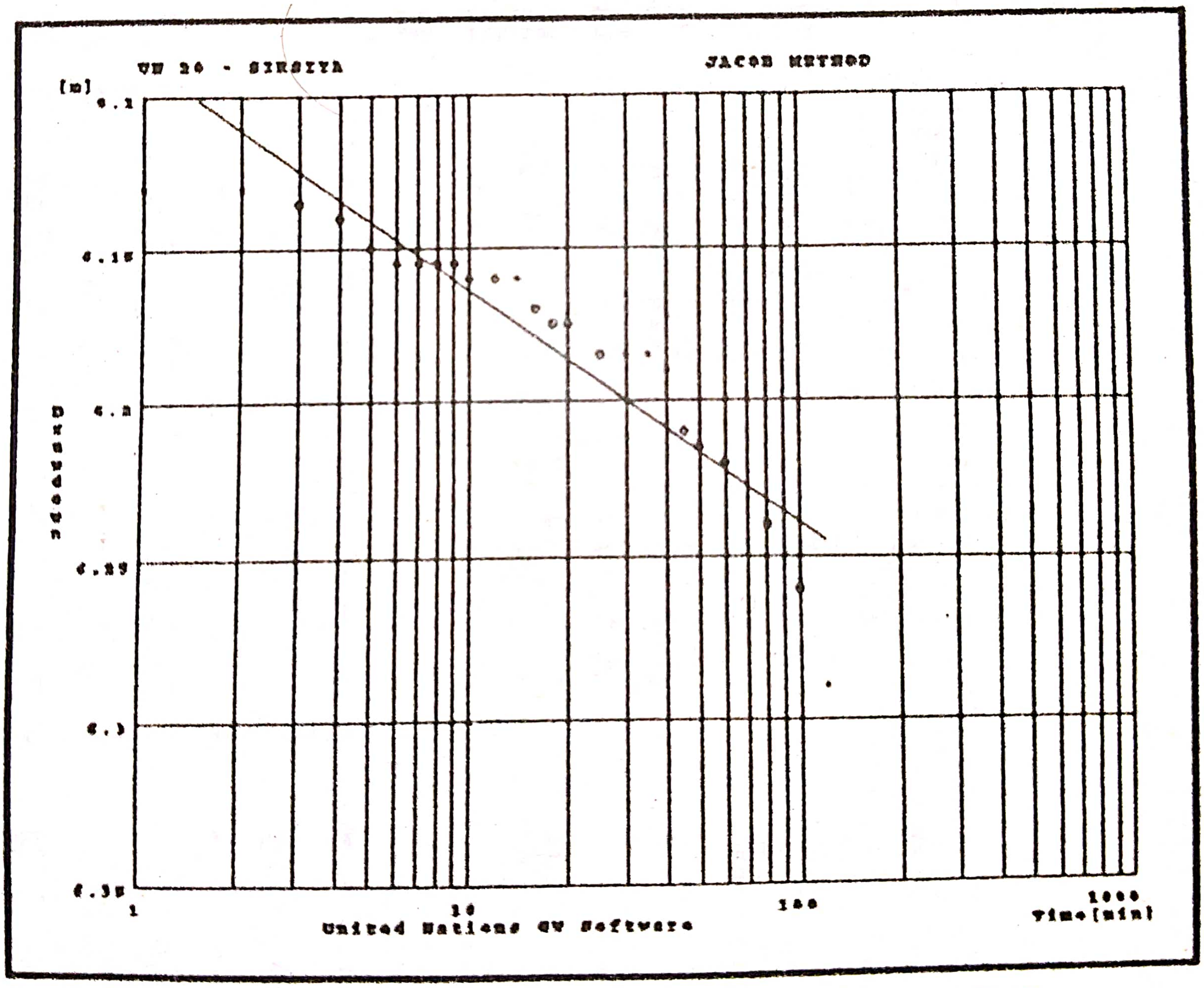
C-9. Pump test of UN 10.



C-10. Pump test of UN 14.



C-11. Pump test of UN 16.



C-12. Pump test of UN 20.

1: Monthly Water Level Measurment Data in Dug Wells in Sarlahi District

e. o.	Village Name	X	Y	Elev. MSL (m) #	Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
						Water Level Measurements in meters (BGL)											
					1987										5.13		3.81
					1988		3.98			3.74		2.70	3.00	1.20	1.25	2.35	2.95
1	Basbaria	347125	2979500	86.00	1989	3.40	3.60	4.00	4.50	5.55	5.63	5.60	5.10	4.05	2.40	2.50	2.70
					1990	2.85	3.02	3.20	3.40	3.65	3.90	3.78	3.75	3.40	3.50	3.55	3.35
					1991	3.68	3.78		5.08	5.40	5.63		4.40	3.60	3.50	3.63	
					1987										1.60		0.53
					1988		0.53			5.08		2.00	2.10	0.95	0.98	1.20	1.33
2	Bhalhi	361125	2972880	80.00	1989	1.43	1.53	1.68	2.10	2.80	2.85	2.87	2.45	2.20	1.70	1.80	1.89
					1990	2.00	2.13	2.20	2.33	2.43	2.40	2.37	2.40	2.20	2.05	1.85	1.75
					1991	2.00	2.20		3.35	3.63	3.70		1.00	1.00	0.75	0.80	
					1987					3.00		1.83			1.31		1.38
					1988		1.45			3.06		1.60	1.75	0.75	0.75	1.65	2.10
3	Bela	361875	2984750	105.0	1989	2.35	2.48	3.03	3.53	4.45	4.50	4.38	3.55	2.45	1.05	1.20	2.03
					1990	2.25	2.40	2.48	2.75	2.90	3.03	2.85	2.95	2.45	2.35	2.45	2.42
					1991	2.50	2.63		3,45	4.00	4.10		2.95	2.05	2.95	2.00	
					1987										3.60		3.70
					1988		3.74			2.22		2.20	2.23	1.22	1.25	1.33	1.40
4	Barhathawa	348500	2986125	99.00	1989	1.45	1.50	1.63	1.90	2.55	2.58	2.55	1.95	1.75	1,25	1.30	1.34
					1990		1.40	1.45	1.58	1.70		1.70	1.90	1.75	1.65		
					1991												
					1987					2.00		1.05			0.57		2.05
					1988		2.11			3.05		1.35	1.38	0.41	0.53	0.75	0.80
4	Chatauna	337750	2964750	73.00	1989	0.88	1.00	1.18	1.50	2.30	2.35	2.35	1.95	1.75	1.20	1.25	1.31
					1990	1.40	1.50	1.60	1.80	1.87	2.90	2.03	1.90	1.75	1.80	1.90	1.87
					1991	1.95	2.15		3.45	3.70	3.83		3.05	1.85	1.70	1.75	
					1987										2.70		2.85
					1988		2.85			4.46		1.15	1.60	0.15	0.30	1.45	1.85
5	Chandranagar	363000	2977500	99.00	1989	2.20	2.55	3.00	3.65	4.55	4.59	4.55	4.00	3.70	3.05		1.93
					1990	2.10	2.30	2.45	2.73	2.95	3.23	3.20	2.90	2.65	3.05	3.17	3.30
					1991	3.38	3.60		4.80	3.50	5.60		4.03	2.90	2.95	3.07	
					1987										1.59		1.64
					1988		1.71			1.79		5.70	6.30	2.10	3.75	4.35	4.85
6	Dungrakhola	351375	2998880	140.0	1989	5.15	5.60	6.10	6.63	7.60	7.55	7.43	6.50	5.70	3.90	4.05	5.33
					1990	4.50	4.65	4.80	5.10	5.33	5.65	5.53	6.65	6.50	5.35	5.40	5.35
					1991	5.45	5.75		6.75	7.60	8.10		6.57	5.35	5.55	5.70	
					1987					3.35		1.50			2.99		2.90
					1988		1.96			2.90		1.37	1.39	0.27	0.42	0.57	1.17
7	Dumaria	342125	2967130	75.00	1989	1.27	1.37	1.57	1.97	2.37	2.40	2.32	1.72	0.97	0.02	0.22	0.42
					1990	0.67	1.00	1.32	1.67	1.90	2.17	2.10	2.32	2.00	2.27	2.70	2.80
					1991	3.35	3.65		4.75	5.40	5.55		3.50	2.50	2.53	2.70	
					1987							4.01			1.55		1.68
					1988		1.74			2.65		1.82	1.57	0.25	1.22	2.07	2.52
8	Gourishankar	369750	2980500	115.0	1989	2.82	3.17	3.57	4.19	5.22	5.34	5.17	4.37	3.22	1.87	1.97	2.10
					1990	2.22	2.40	2.52	2.82	3.07	3.27	3.10	3.32	2.97	3.07	3.22	3.25
					1991	3.37	3.52		4.62	5.17	5.42		4.17	3.12	2.72	2.64	
					1987										1.26		
					1988					3.05		2.45	2.50	0.53	0.70	2.65	3.25
9	Ghusukpur	369625	2976500	100.0	1989	3.55	3.70	4.13	4.50	5.62	5.65	5.45	4.60	3.55	1.80	2.95	3.05
					1990	3.20	3.30	3.43	3.65	3.83	3.95	3.70	3.65	3.25	3.20	3.33	3.40
					1991	3.53	3.70		4.60	5.03	5.10		3.70	2.65	2.65	2.75	
					1987											5.93	4.44
					1988		4.48			3.92		3.68	3.69	2.35	2.42	2.57	2.67
10	Harpurwa	343875	2981250	90.00	1989	2.77	2.82	2.95	3.13	3.87	4.10	3.82	3.07	2.17	1.02	1.22	1.32
					1990	1.52	1.77	1.92	2.12	2.37	2.67	2.52	2.97	2.82	2.67	2.81	2.87
					1991	3.02	3.22		4.62	5.02	5.25		3.92	3.12	2.95	3.05	
					1987										0.55		2.08
					1988		3.55			2.48		1.97	2.00	1.05	1.77	1.92	2.07
11	Haripur	360250	2989750	116.0	1989	2.15	2.22	2.37	2.67	3.22	3.25	3.23	2.77	2.62	2.07	2.15	2.22
					1990	2.32	2.45	3.67	2.62	2.70	2.87	2.77	2.87	2.72	2.57	2.65	2.57
					1991	2.77	2.97		3.02	4.12	4.20		3.42	2.82	2.97	3.02	

& Y = Landsat Coordinates, m = meter, # = Elevation from Topomap, BGL = Below Ground Level

D1 cont...

S. No.	Village Name	X	Y	Elev. MSL (m) #	Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
						Water Level Measurements in meters (BGL)											
					1987					5.50					2.47		2.55
					1988		2.25			7.98		3.30	3.65	1.50	1.58	2.35	2.95
12	Jamunia	352375	2978500	86.00	1989	3.20	3.65	4.18	4.70	5.85	5.98	5.95	5.10	4.00	2.10	2.28	2.45
					1990	2.60	2.83	2.95	3.15	3.35	3.70	3.48	3.70	3.05	3.17	3.38	3.35
					1991	3.60	3.80		5.10	5.55	5.65		3.95	3.05	2.95	3.00	
					1987							2.25			1.10		2.45
					1988		1.46			3.35		0.30	0.33	0.10	0.35	0.45	0.75
13	Koodena	352250	2971750	81.00	1989	1.05	0.83	1.00	1.35	2.10	2.05	2.03	1.65	1.48	1.00	1.03	
					1990	1.15	1.23	1.20	1.33	1.42	1.40	1.35	1.60	1.50	1.58	1.50	1.50
					1991	1.57			3.20	3.48			2.45	1.20	1.15	1.28	
					1987					8.80		3.02			0.88		0.93
					1988		0.97			3.50		8.25	8.27	7.13	7.00	7.05	7.70
14	Lalbandi	364625	2991750	150.0	1989	7.75	7.83	7.95	8.10	8.70	8.70	8.65	7.80	7.55	7.10	7.45	7.23
					1990	7.30	7.37	7.43	7.55	7.65	7.80	7.75	7.55	7.35	7.05	6.98	6.95
					1991	6.90	6.98										
					1987							1.85			2.88		0.46
					1988		0.55			4.65		3.55	4.15	3.70	2.12	2.92	3.42
15	Mohanpur	362125	2997250	163.0	1989	3.77	4.05	4.58	5.05	6.30	6.55	6.47	5.55	4.75	3.05	3.10	3.25
					1990	3.50	3.70	3.80	4.05	4.35	4.70	4.60	4.05	3.95	4.25	4.50	4.43
					1991	4.55	4.67		5.80	6.75	7.05		5.25	3.85	3.95	4.05	
					1987					2.40		1.15			1.98		2.05
					1988		2.23			2.68		2.35	2.62	0.67	0.80	2.15	2.75
16	Mahinathpur	342625	2974750	80.00	1989	3.23	3.52	3.97	4.20	5.32	5.42	5.35	4.72	3.62	2.42	2.60	2.75
					1990	2.92	3.10	3.20	3.47	3.65	3.89	3.77	3.92	3.52	3.42	4.57	4.52
					1991	4.62	4.79		6.12	6.57	6.87		4.90	3.57	2.90	2.98	
					1987												
					1988		1.14			3.60		3.47	3.97	2.00	2.02	2.87	3.47
17	Mohanpur	359750	2979130	90.00	1989	3.77	4.27	4.79	5.11	5.97	6.05	5.97	5.32	4.47	3.07	3.12	3.27
					1990	3.37	3.55	3.67	3.92	4.17	4.32	4.17	4.32	4.07	3.67	3.82	3.87
					1991	4.02	4.22		5.17	5.62	5.82		4.47	3.32	3.27	3.42	
					1987										1.15		2.47
					1988		2.47			4.84		2.10	2.13	0.85	1.00	1.10	1.25
18	Malangwa	357250	2971375	83.00	1989	1.35	1.45	1.65	1.95	2.60	2.67	2.70	2.20	1.95	1.30	1.40	1.48
					1990	1.58	1.65	1.70	1.88		1.90	1.80	2.00	1.90		1.70	1.67
					1991												
					1987					3.35		2.90			0.60		0.68
					1988		0.64			3.17		2.90	2.45	0.20	1.28	2.20	2.75
19	Piparia	354375	2984750	102.0	1989	3.15	3.70	4.15	4.78	5.85	5.95	5.90	5.05	3.85	2.15	2.30	2.46
					1990	2.64	2.80	2.93	3.18	3.28	3.65	3.00	3.85	3.57	3.15	3.35	3.38
					1991	3.45	3.58		4.65	5.05	5.28		3.80	3.00	2.70	2.80	
					1987					16.7		15.5			7.6		10.7
					1988		11.0			13.2		12.4	12.9	9.5	8.3	9.0	9.5
20	Raniganj	370000	2992750	200.0	1989	9.6	9.8	10.1	10.6	11.8	11.8	11.6	11.0	9.9	8.0	8.1	8.2
					1990	8.4	8.6	8.7	8.8	9.1	9.3	9.2	11.1	11.0	11.4	11.5	11.5
					1991	11.6	11.7		14.6	15.8	16.3			11.2	11.7	11.7	

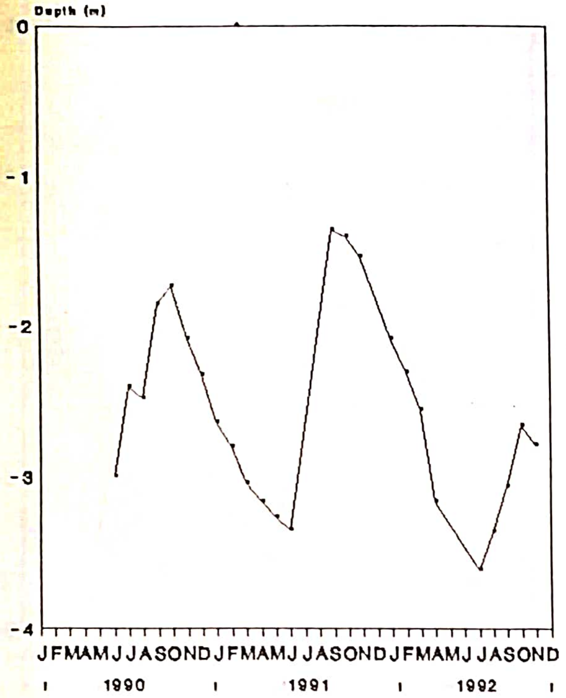
X & Y = Landsat Coordinates, m = meter, # = Elevation from Topomap, BGL = Below Ground Level

nthly Water Level Measurment Data in U.N. Wells in Sarlahi District

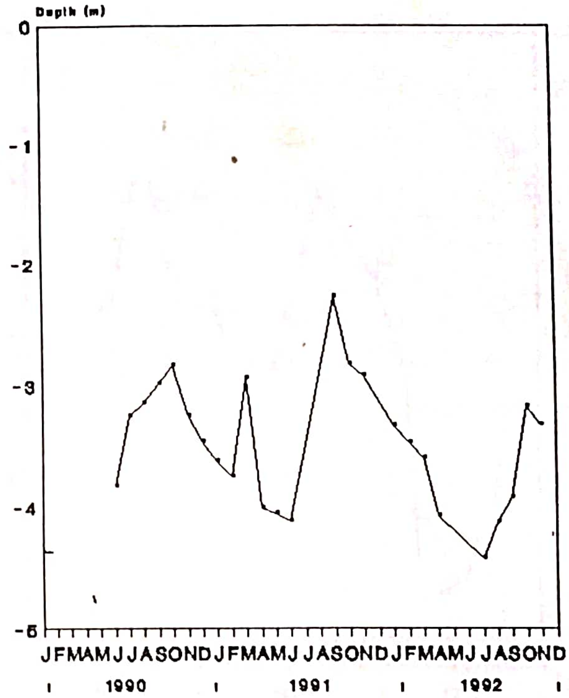
No.	Village Name	X	Y	Elev. MSL (m) #	M.P. (m)	Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
							Wter Lvel Masureents in metrs (BGL)											
1	Sitapur	349410	2986400	97.00	0.74	1990						3.00	2.40	2.48	1.86	1.74	2.09	2.33
						1991	2.64	2.80	3.04	3.16	3.26	3.35			1.36	1.41	1.54	
						1992	2.09	2.31	2.56	3.16			3.61	3.36	3.06	2.66	2.76	
2	Hajariya	344115	2987400	99.20	0.67	1990						3.84	3.26	3.15	2.99	2.84	3.26	3.47
						1991	3.63	3.76	2.95	4.02	4.06	4.12			2.28	2.83	2.93	
						1992	3.35	3.48	3.61	4.08			4.43	4.13	3.93	3.18	3.33	
3	Bhawanipur	344950	2976400	86.70	0.89	1990						2.23	2.00	1.48	1.08	1.27	2.14	2.76
						1991	2.61	2.31	2.50	2.66	2.40	2.46			0.66	1.41	1.40	
						1992	1.76	2.00	2.31	3.11			3.56	3.11	2.86	2.21	2.11	
4	Aurahi	350900	2974650	87.90	0.57	1990						3.16			0.80	0.36	1.42	1.69
						1991		3.39	4.75	4.80	5.21	5.32			3.85	3.95	4.10	
						1992	4.65	4.80	5.05	5.65			6.30	6.00	3.60	4.70	4.85	
5	Shanakpur	348650	2591200	101.2	0.65	1990						6.88	5.65	5.45	4.33	3.77	4.35	4.99
						1991	5.65	6.01	6.50	6.58	6.84	7.09			3.75	3.70	3.77	
						1992	4.00	4.10	4.20	4.65			5.12	4.55	3.35	2.60	2.68	
6	Haripur	359600	2989000	114.5	0.82	1990						4.25	3.37	3.96	3.18	2.58	2.33	2.49
						1991	2.71	2.93	3.35	3.64	3.97	4.37			1.93	2.18	2.38	
						1992	2.88	3.13	3.38	3.88			4.33	3.98				
7	Shishaut	345460	2971350	77.10	0.40	1990						1.87	1.79	1.22	0.80	1.16	1.69	2.00
						1991	1.83	1.89	2.11	2.07	2.36	2.25			1.10	1.20	1.35	
						1992	1.65	1.99	2.30	3.78			3.60	3.30	3.10	2.40	2.55	
8	Bairiya	338260	2970550	78.00	0.73	1990						1.62	1.54	1.02	0.44	0.89	1.52	1.74
						1991	1.72	1.84	1.98	2.04	2.10	2.12			0.60	0.72	1.07	
						1992	1.42	1.72	2.10	2.52			3.32	3.07	2.97	2.37	2.45	
9	Balara	338200	2962200	72.70	0.49	1990						1.91	1.76	1.94	1.24	0.26	1.56	1.91
						1991	1.91	2.10										
						1992								3.30	2.95	2.30	2.20	
10	Madhuban	346990	2964970	75.30	0.56	1990						1.68	1.40	0.90	0.58	0.27	1.38	1.68
						1991	1.69	1.92	2.23	2.31	2.44	2.58			1.02	1.44	1.52	
						1992	1.53	1.92	2.24	2.65			3.49	3.24	3.04	2.34	2.42	
11	Lalbandi	366500	2991720	148.0	0.67	1990						8.42	7.02	6.10	4.54	3.99	3.76	3.98
						1991	4.38	4.79	5.40	6.13	6.63	7.41			4.43	4.63	4.75	
						1992	5.18	5.33	5.68	6.28			6.83	6.43				
12	Bayalbas	363000	2987400	125.0	0.63	1990						0.99	0.88	0.50	0.28	0.41	1.37	1.52
						1991	1.46	1.60	1.97	2.00	2.14							
						1992									6.57	6.37	6.07	
13	Pokhariaya	361990	2978700	100.0	0.57	1990						1.57	1.49	1.06	0.83	0.88	1.68	1.94
						1991	2.22	2.36	2.65	2.79	2.95	3.11			0.85	0.88	1.13	
						1992	1.53	1.78	2.08	2.58			3.18	2.95	2.53	2.33	2.11	
14	Malangawa	357150	2971200	83.10	0.70	1990						2.49	1.31	1.21	0.82	0.88	1.67	2.05
						1991	2.48	2.72	3.01	3.09	3.29	3.43			1.20	1.20	1.28	
						1992	1.65	2.00	2.30	2.95			3.40	3.15	2.50	1.95	1.80	
15	Shreenagar	373000	2985000	135.6	0.54	1990						8.71	8.65	7.86	7.43	7.21		7.06
						1991	6.06	6.20	8.13	8.41	8.56	8.81			8.75	8.46		
						1992									7.56	6.96	6.66	
16	Jingarwa	368200	2975400	90.30	0.75	1990						0.57	0.54	0.27	0.11	0.35	1.11	1.32
						1991	1.41	1.44	1.63	1.70	1.87	1.95			0.50	0.50	0.57	
						1992	1.25	1.50	2.00	2.55			3.25	3.00	2.45			
17	Basantapur	369900	2978260	104.8	0.42	1990						1.00	0.95	0.55	0.61	0.68	1.58	1.87
						1991	2.00	2.13	2.48	2.64	2.73	2.76			0.83	0.88	0.92	
						1992	1.73	1.98	2.28	2.86			3.43	3.28	2.68	1.58	1.68	
18	Nabalpur	360180	2994430	150.0	0.46	1990						9.66	6.97	6.16	5.44	4.79	5.20	5.57
						1991	6.44		7.70	7.89	8.25	8.67			5.30	5.70	6.05	
						1991	6.80	7.20	7.35	8.15			9.80	9.30	8.30	7.30	6.90	
19	Hariaun	356900	2996700	145.0	0.80	1990						11.19	10.14	9.55	7.38	5.67	6.41	6.8
						1991	7.70	8.25	8.89	9.38	10.2	10.75			6.00	7.40	7.90	
						1992	8.83	9.20	9.58	10.2				11.4	10.5	9.40	9.50	
20	Shirshiya	356500	2981400	86.70	0.68	1990							4.04	1.47	0.57	0.54	1.67	2.0
						1991	2.31	2.46	2.82	2.99	3.17	3.39			1.17	1.27	1.40	
						1992	1.77	2.17	2.42	2.92			3.42	3.27	2.72	1.92	2.00	

X & Y = Landsat Coordin tes, m = meter, # = Elevation from Topomap, BGL = Below Ground Level

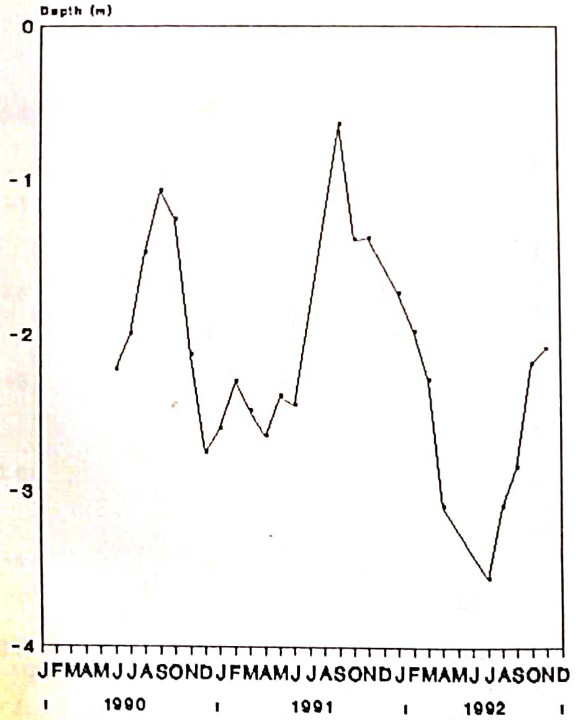
HYDROGRAPH OF SITAPUR (UN-1)



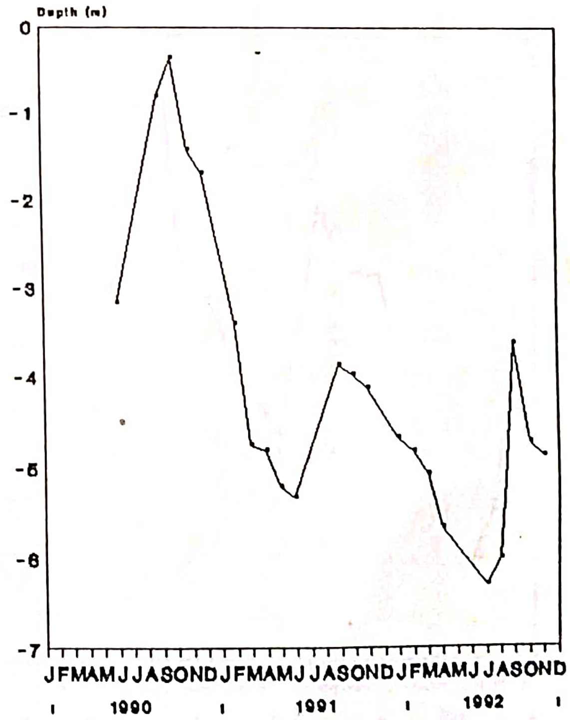
HYDROGRAPH OF HAJARIYA (UN-2)



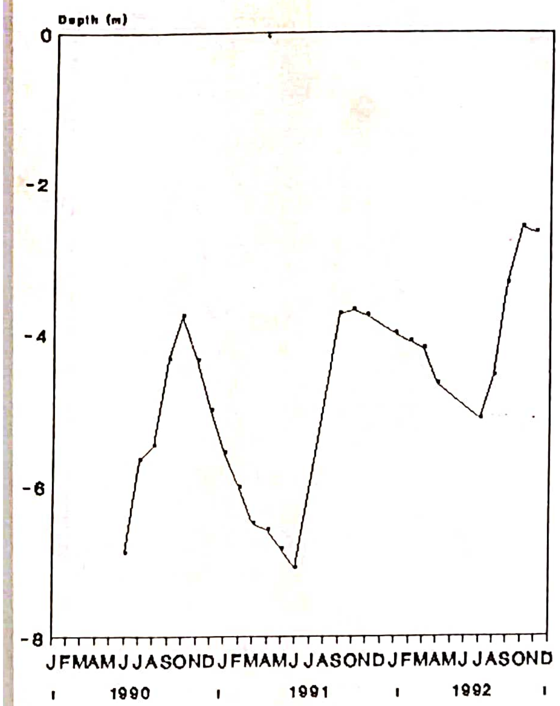
HYDROGRAPH OF BHAWANIPUR (UN-3)



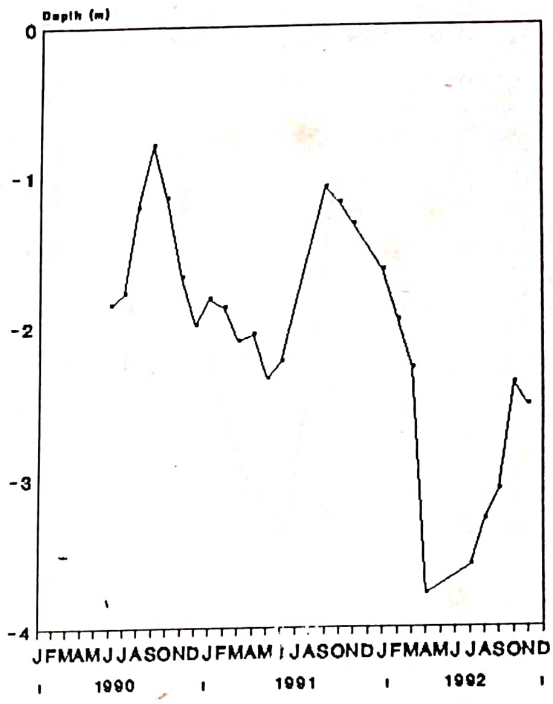
HYDROGRAPH OF AURAHI (UN-4)



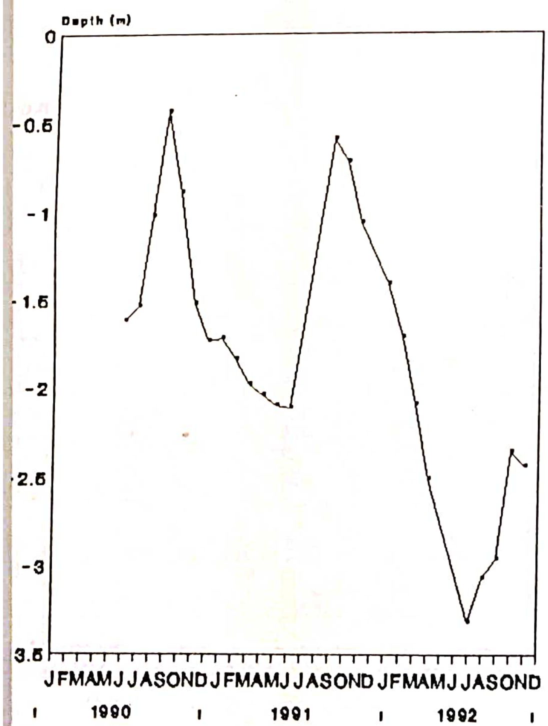
HYDROGRAPH OF SANAKPUR (UN-5)



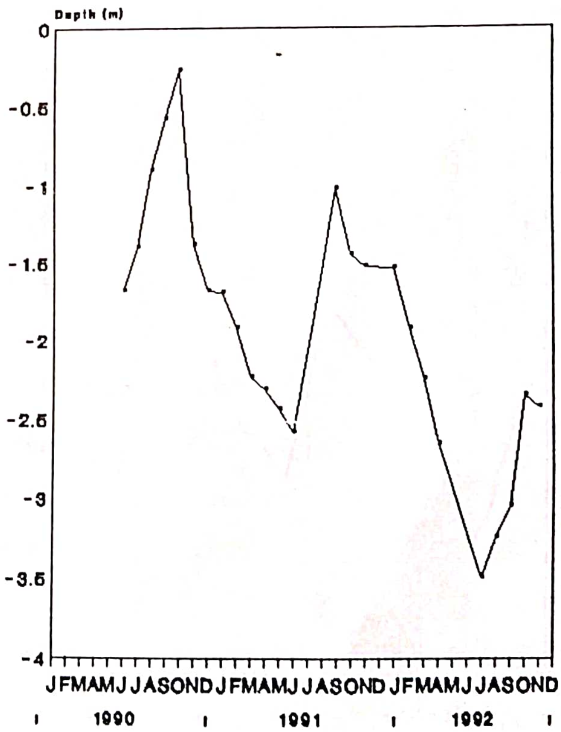
HYDROGRAPH OF SHISHAUT (UN-7)



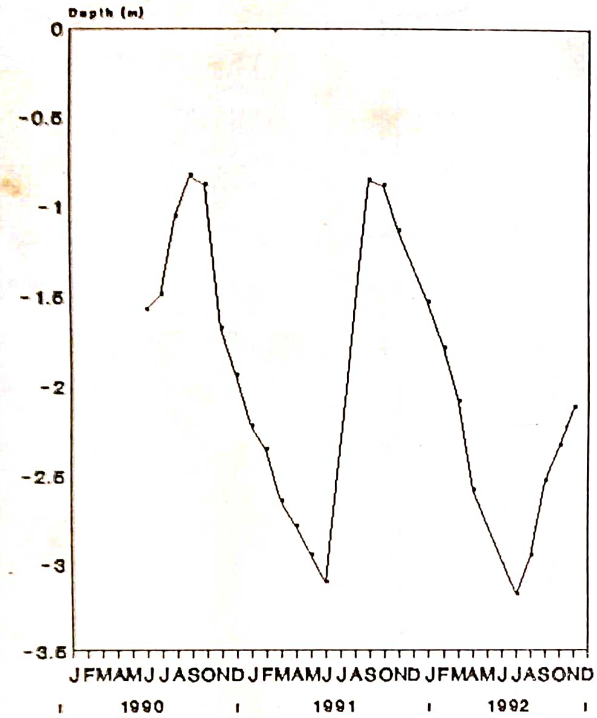
HYDROGRAPH OF BAIRIYA (UN-8)



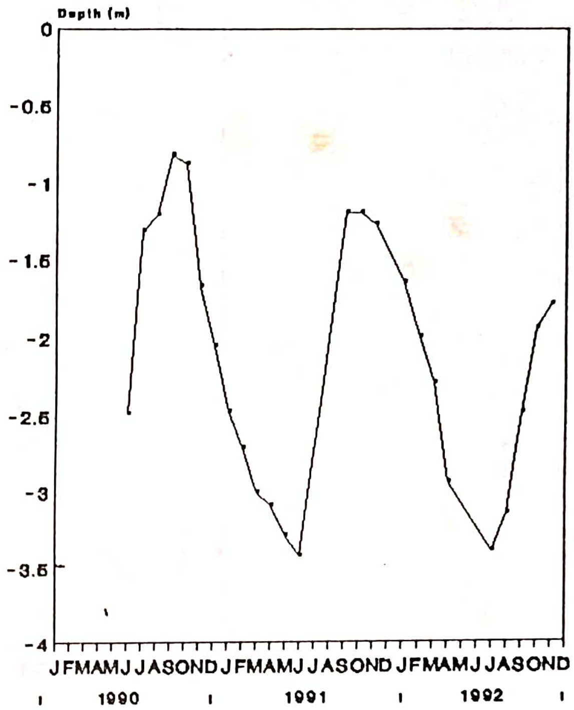
HYDROGRAPH OF MADHUBAN (UN-10)



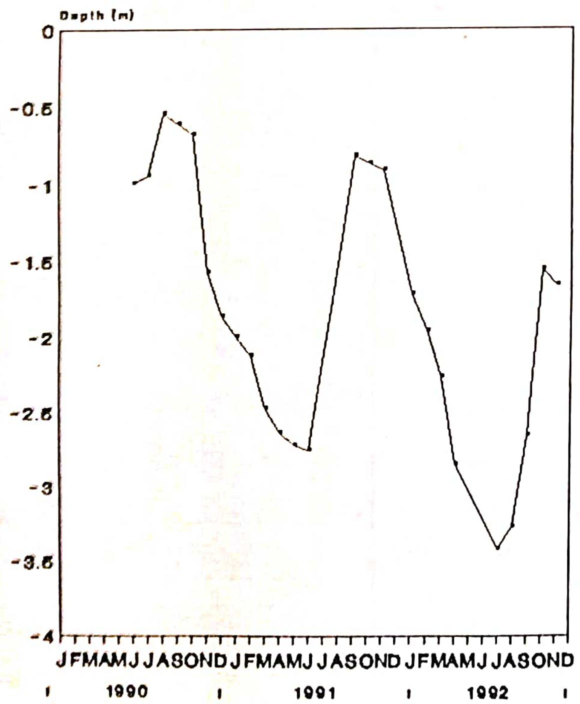
HYDROGRAPH OF POKHARIYA (UN-13)



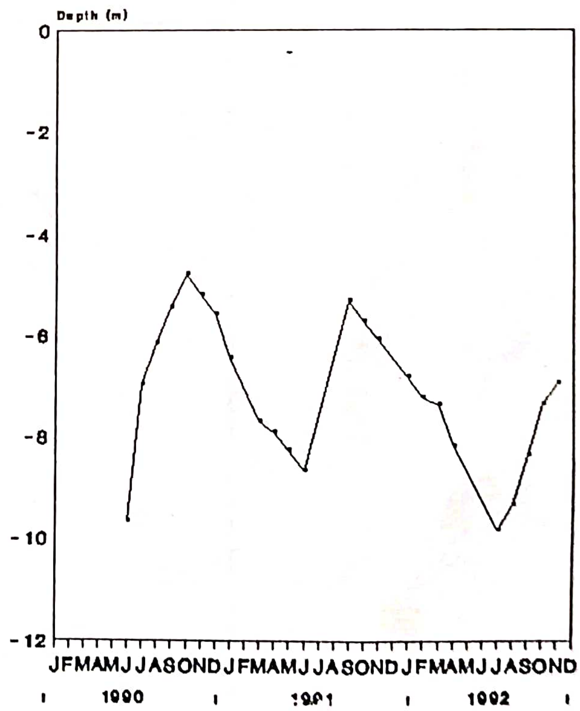
HYDROGRAPH OF MALANGAWA (UN-14)



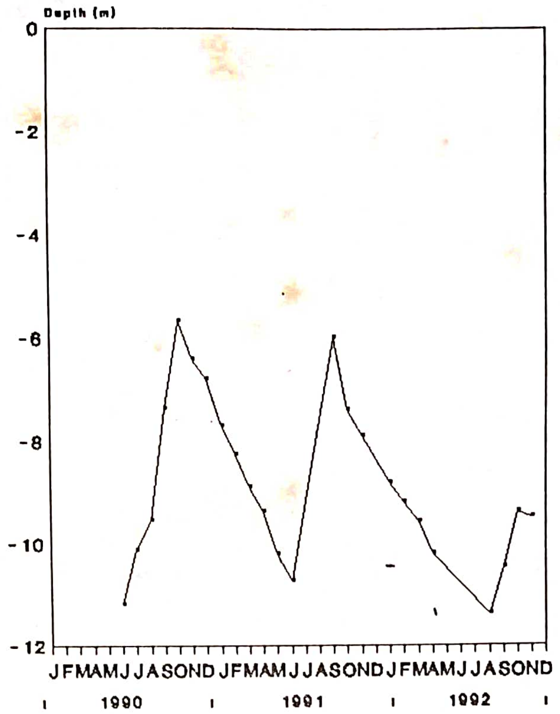
HYDROGRAPH OF BASANTAPUR (UN-17)



HYDROGRAPH OF NABALPUR (UN-18)



HYDROGRAPH OF HARAIAUN (UN-19)



HYDROGRAPH OF SHIRSHIYA (UN-20)