ELECTRICAL ANALOG STUDY OF GROUND WATER CONDITIONS IN A PART OF UPPER YAMUNA BASIN

A DISSERTATION
submitted in partial fulfilment
of the requirements for the award of the Degree
of
MASTER OF TECHNOLOGY
in
HYDROLOGY

By
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ROORKEE (INDIA)
June, 1976

C E R T I F I C A T E

This is to certify that the dissertation entitled "Electrical Analog Study of Ground Water conditions in a part of Upper Yamuna basin" being submitted by Mr. Mahendra Datt Nautiyal in partial fulfilment of the requirements for the award of the degree of Master of Hydrology of the University of Roorkee, Roorkee is a record of candidate's own work carried out by him under my supervision and guidance. The material embodied in this dissertation has not been submitted for the award of any other degree or diploma.

This is to certify that Mr. M.D. Nautiyal worked for nine months for his dissertation.

June 9th, 1976

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Associate Professor, Hydrology
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I take this opportunity to thank my friends and colleagues in the Department of Geology and Geophysics, University of Roorkee and Central Ground Water Board for the help and cooperation extended during this work.

M.D. Nautiyal

ABSTRACT

The Upper Yamuna basin is an important river basin for its water resources. Efforts are being made by the various beneficiary states for the optimum utilization of its water resources. With this end in view Haryana Govt. have installed battery of heavy duty tubewells along a newly constructed lined canal located in the investigated part of the basin. The lean period flow of about thirty cumecs of western Yamuna canal is diverted into the lined canal in order to check the seepage loss from old unlined western Yamuna canal. The lined augmentation canal is fed by the discharge of 160 augmentation wells also, the cumulative discharge of these augmentation wells being 14 cumecs. This would naturally effect the existing hydrological equilibrium in the basin. To study the effect of this increased pumpage by the augmentation wells, an R-C analog model of a part of Upper Yamuna basin was designed and developed.

The model was designed by applying conformal mapping technique for mapping and simulating aquifer of infinite extent. The values of resistors in the model were kept constant but the values of capacitors were changed depending upon the variation in transmissivity and storativity of the aquifer.

The model was first tested by comparing the analog and the analytical results. The effects of augmentation wells on water

levels was also investigated with the help of analog model which indicates that a discharge of 1097650 cu.mt/day for 121.6 days pumping causes a drawdown of about 10 metres close to the battery of wells.

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C O N T E N T S

CHAPTER- 1

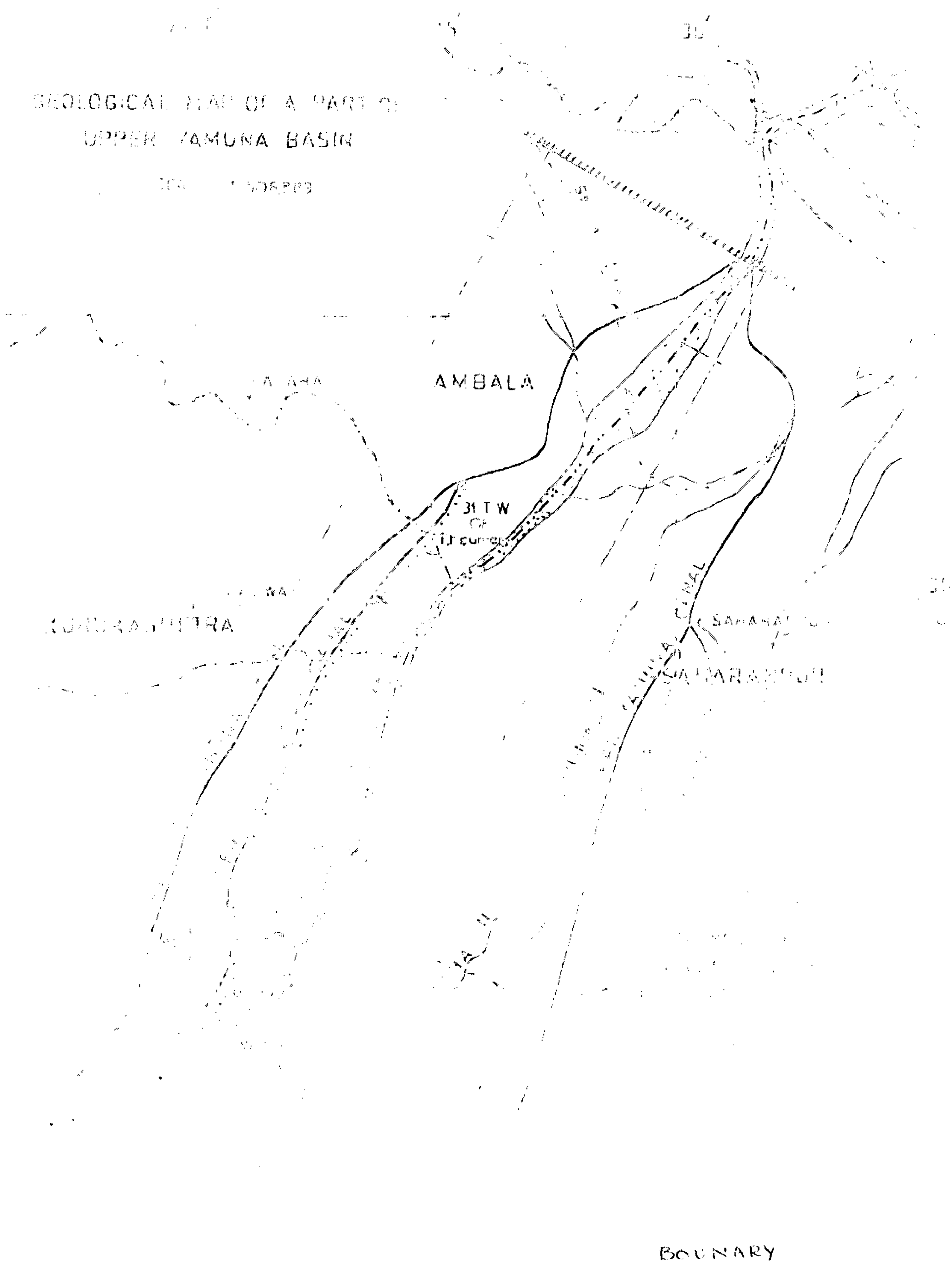
INTRODUCTION

1.1 General

The Yamuna river originating from Bandarpunch beyond Yamnotri in greater Himalayas and traversing the mountainous tract emerges into the plains through Siwalik foot hills near Tajewala(Yamuna joins river Ganga at Allahabad). Tons and Giri form its main tributaries in the upper reaches. The Upper Yamuna basin (as defined by C.W.C.)comprises of parts of Himachal Pradesh,Uttar Pradesh,Haryana and Delhi.

The mountainous tract with its outlet near Tajewala has little significance from ground water point of view. However,in the plain country south of Tajewala efforts are being made for the optimum utilisation of ground water resources. At Tajewala surface flows of Yamuna are tapped by Eastern and Western Yamuna canals irrigating parts of U.P. and Haryana respectively. Normally the lean period inflow at Tajewala is totally diverted to the Canal system and rarely when either the discharge is high due to rainfall ox or the canal is closed due to some reason or other the excess flow is released in the Yamuna. Downstream of Tajewala the river which is initially dried up gradually starts receiving effluent seepage from ground water body and the regeneration reaches a figure of about 5 to 6 cumecs at Delhi

PLATE I.



where the river is again tapped for water supply to Delhi Metropolitan and for feeding Agra Canal.

The appreciable pace of ground water development in this part of the basin has to be viewed with caution. The beneficiary states particularly which are deficient in water resources are depending more on ground water. Recently Haryana installed a battery of heavy duty tubewells along a newly constructed lined canal of 141.6 cumecs(5000 cusecs) capacity. The cumulative discharge of the wells being about 14 cumecs(500 cusecs).The new lined canal takes off from Western Yamuna Canal at Yamunanagar and joins western Yamuna canal at Munak(plate 1).The lean period discharge of about 60 cumecs of western Yamuna canal is diverted through the new lined canal.

The upper reaches of western Yamuna canal was constructed by using abandoned river course of Yamuna due to which there is excessive loss in the upper reaches of the Canal. The new lined canal will check the seepage loss to ground water body and collect the additional discharge of augmentation wells installed along the lined canal.This is expected to upset the existing hydrological balance and adversely affect the regeneration to the river Yamuna.The regeneration to the Yamuna is fully utilised downstream for feeding Agra Canal of U.P. A controversy has arisen between the beneficiary states of Upper Yamuna basin i.e. U.P. and

Haryana regarding the effect of augmentation wells on the regeneration to river Yamuna.

To study the behaviour of the ground water regimen and the effect of the augmentation tubewells on the ground water condition of this part of the Upper Yamuna basin an electrical analog model was developed at the University of Roorkee.

The analog model is designed on the basis of hydrogeological data collected by the Haryana State Minor Irrigation Tubewell Corporation(H.S.M.I.T.C.) during the investigation for assessment of ground water resources of this part of the basin.

As a part of these investigations, H.S.M.I.T.C. drilled fifteen exploratory boreholes which were converted to production wells. Pumping tests were carried out on seven wells and the values of transmissivity and storavity thus obtained were utilised in designing the present analog model.

1.2 Physiography

The important drainage course in the area of study is river Yamuna and some ephemeral streams like Somb Nadi, Maskara Rao etc. originating from Siwalik hills. Most of the precipitation falling over Siwalik hills contributes to surface run off of these ephemeral streams. Upper reaches of Yamuna basin has a distinct drainage basin upto Tajewala because of Siwaliks forming a water divide in the lower reaches. Run off coming down to lower reaches of Upper Yamuna basin is through Yamuna at Tajewala.

The upper reaches of the Yamuna basin is a mountainous terrain bounded by Siwalik hills in the south. South of the Siwalik hills is, the Bhabar belt comprised of piedmont deposits. The Bhabars are integrated alluvial fans which merge into the main alluvial plain. The Bhabars being fan deposits have a steep slopes which gradually become gentler further south. The master slope of the area is NE to SW. There are some topographical depressions resulting in ponding of rain water. At places gully formation and bad land topography is noticed particularly in the Bhabar region.

1.3 Hydrometeorology

There is a large seasonal variation in the meteorological conditions in the area which varies from season to season. Normal humidity, atmospheric temperature and wind velocity at Karnal are given in table 1.1.

TABLE -1.1

Months	Humidity %	Temperature in °C		Wind velocity
		Maximum	Minimum	Km/hour
January	79	20.1	7.0	-
February	73	24.0	9.2	7.3
March	64	29.4	14.1	8.4
April	45	35.7	19.3	8.5
May	41	39.7	24.2	7.0
June	55	39.6	26.2	7.8
July	79	34.9	25.7	7.0
August	85	32.9	25.0	4.1
September	79	33.3	23.6	-
October	73	31.5	17.3	-
November	64	23.0	11.9	-
December	71	22.8	8.4	-

The annual rainfall in this part of the basin for 1967-1974 period is given in Table 1.2.

TABLE 1.2

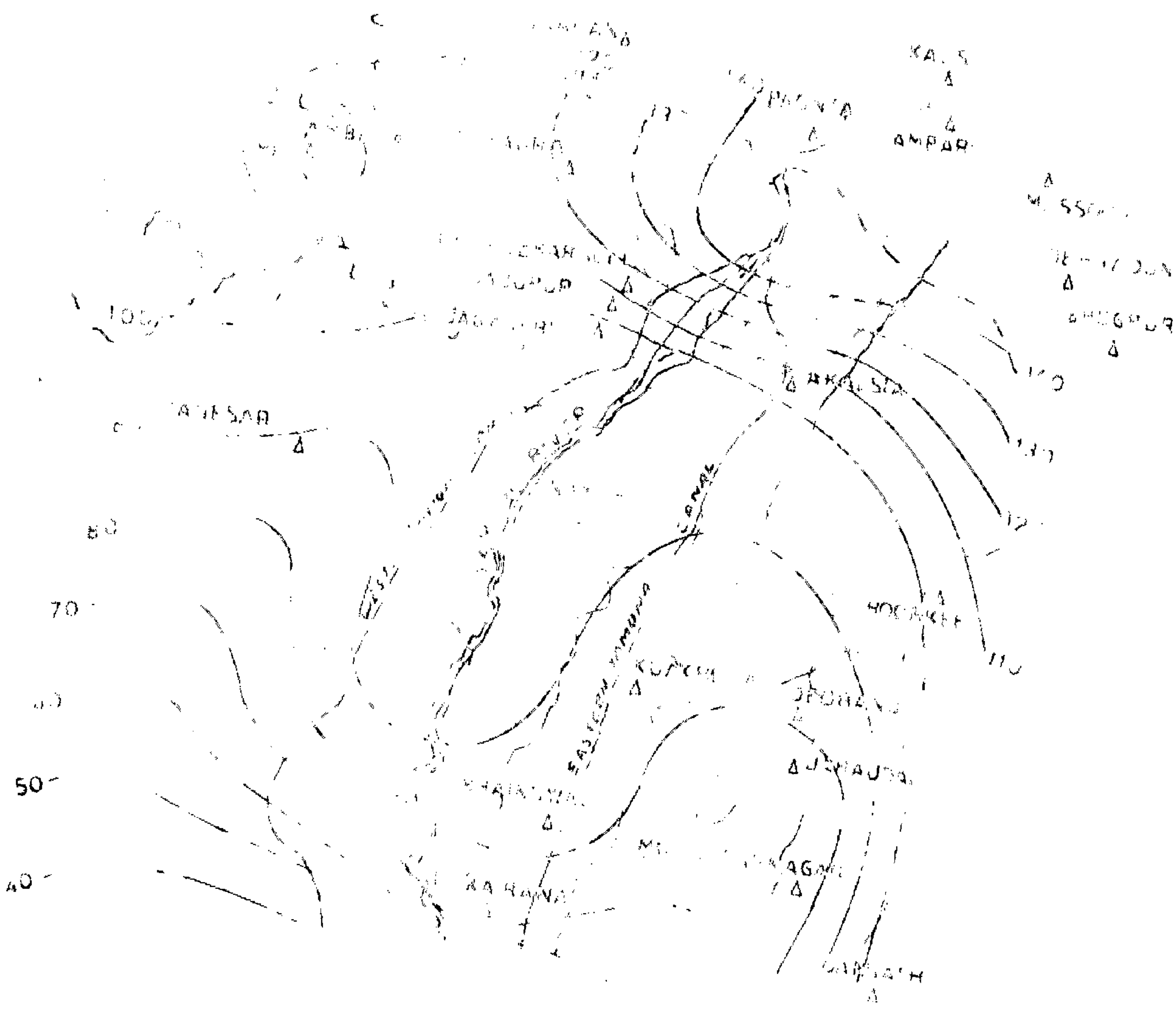
Year	Rainfall mm	Year	Rainfall mm
1967	1140	1971	1130
1968	960	1972	890
1969	730	1973	880
1970	950	1974	530

The main source of recharge to ground water body is rainfall. The average rainfall for the area of study being 1001 mm. with 1375 mm. and 530 mm. as the highest and lowest rainfall in the year 1942 and 1974 respectively. The isohyetal maps of average, highest & lowest rainfall are given in plate II, III and IV respectively.

1.4 Ground Water Quality

On the basis of chemical analysis carried out by the Haryana State Minor Irrigation Tubewell Corporation is is observed that the quality of ground water is generally fit for irrigation and domestic use.

PLATE II



ANNUAL RAINFALL IN A PART OF UPPER YAMUNA BASIN IN 1942

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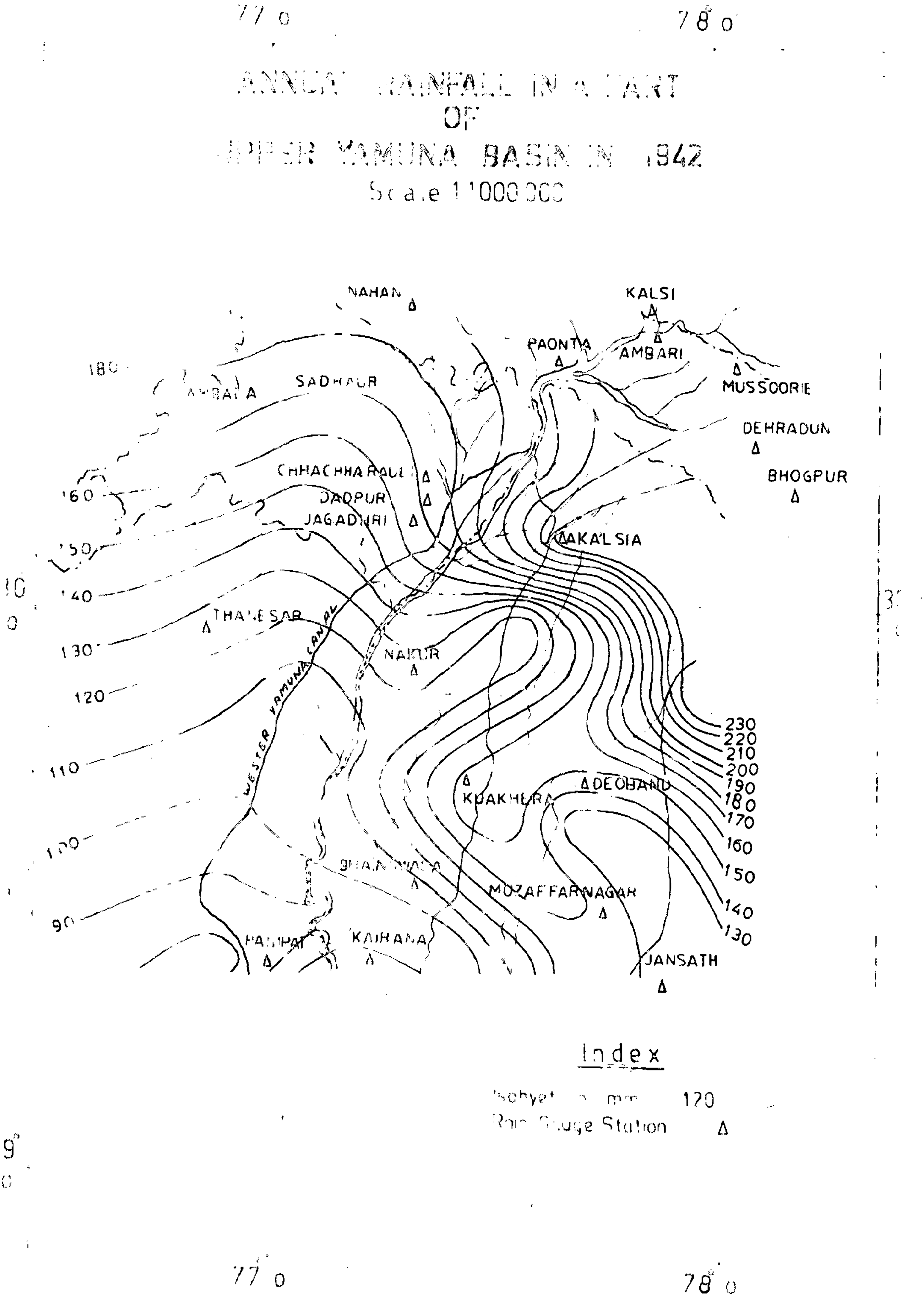

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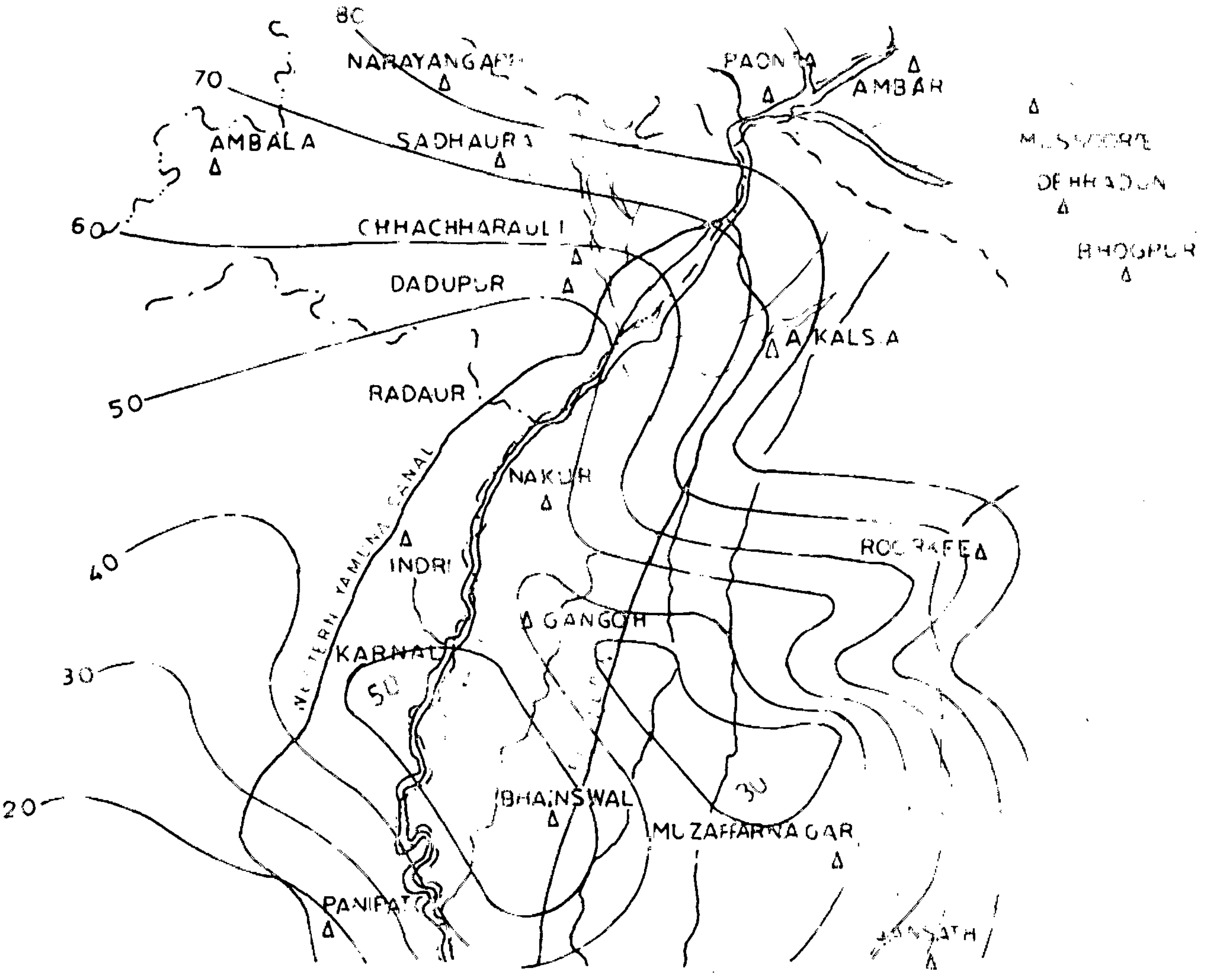
Isohyet in mm 120

Rain Gauge Station Δ

ANNUAL RAINFALL IN PART OF UPPER YAMUNA BASIN IN 1974



Index
Isohyet
Rain Gauge

CHAPTER - 2

GEOLOGY

2.1 Geological setting

The area is covered by monotonous fluviatile deposits of Pleistocene to Recent age. The sediments were deposited after the final upheaval of the Himalaya and has continued all through the Pleistocene to present time. The geological succession of the various formations in the area may be given as follows:

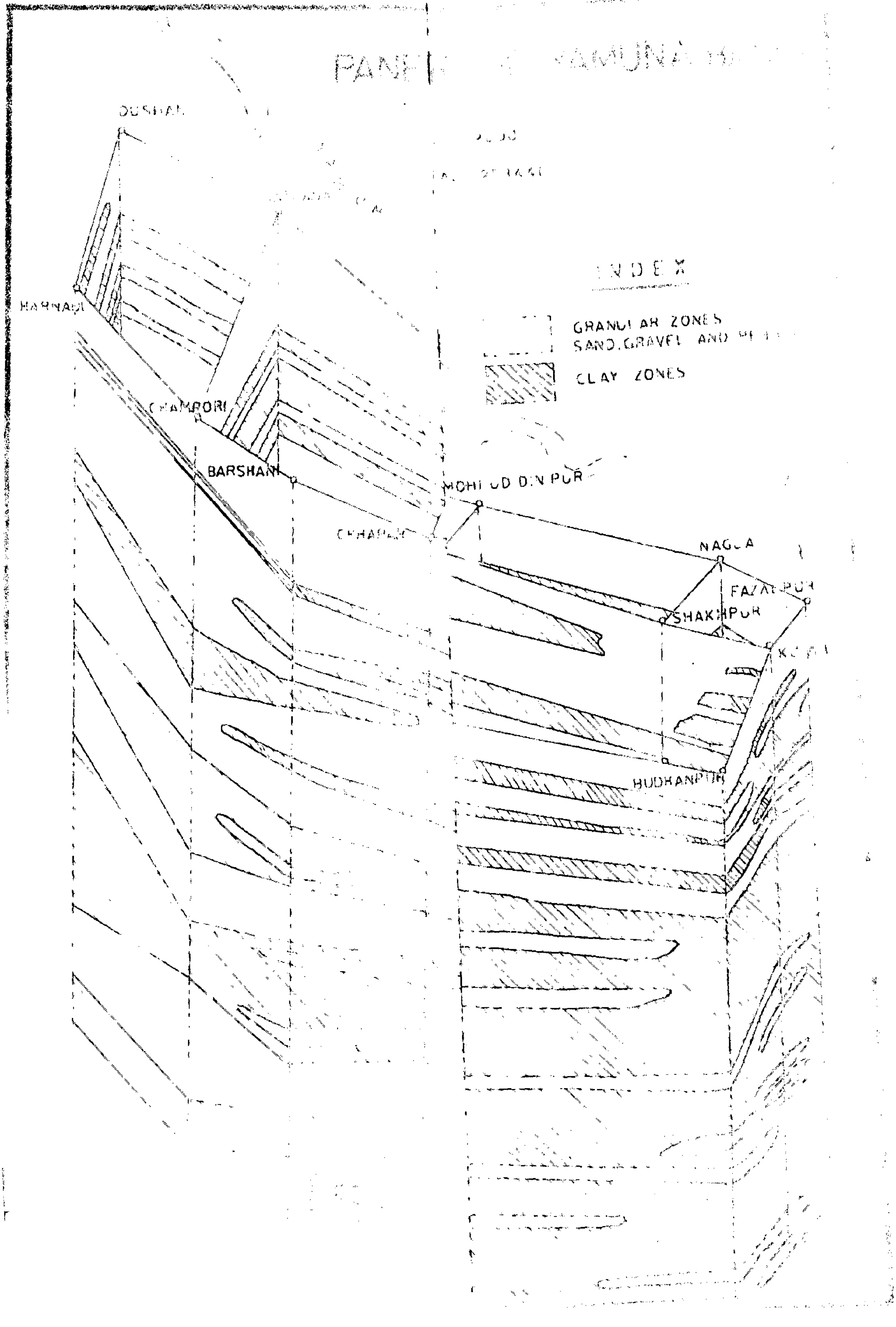
Quarternary	Recent, Newer allivium, unconsolidated sand silt and clays. Pleistocene-older alluvium, clay, Kankar, silt, sand and gravel.
Archean/Vindhyans?	Basement

The deposits are derived from the denudation and erosion of mainly the metamorphic and sedimentary rocks of the Himalaya. The sediments were brought down by the terbulant Himalayan rivers particularly during the time of floods. The sediments being typical flood plain deposits.

The alluvial thickness of the Upper Yamuna basin is maximum in the area of study. The thickness varies from 4000 mt. to 1000mt. from north to south. Further towards south the basin starts shallowing rapidly near Munak due to a flaxure. The sediments in the south are distinct in character which represent the finer deposits of the basin.

2.2 Sub-surface Geology

Although the area is underlain by a thick pile of sediments only a limited thickness mostly upto a depth of 300 mt. has been explored for ground water development . On the basis of lithology of 15 boreholes drilled by Haryana State Minor Irrigation Tubewell Corporation panel diagram depicting the sub-surface geology has been prepared (Plate V). The diagram indicates five prominent aquifer groups. As is evident from the diagram the northern part of the area of study is predominantly sandy, whereas southward sand to clay ratio decreases as the lithology progressively becomes more argillaceous(clayey). The granular(sandy) zones of the area form prolific source of ground water. On comparing the geology of this part of the basin with the area further southward it appears that the aquifers are pinching out towards south. The aquifers encountered further south at borehole Naultha (29°20', 76°53') are distinctly different from the aquifers of augmentation canal project area and it may be concluded that the aquifers are terminating along the southern boundary of the area of study. Therefore, in preparing the analog model this has been taken to be the sub-surface barrier boundary. Similarly the northern extension of the aquifers may be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BARSHANI
MOHI UD DIN PUR
NAGLA
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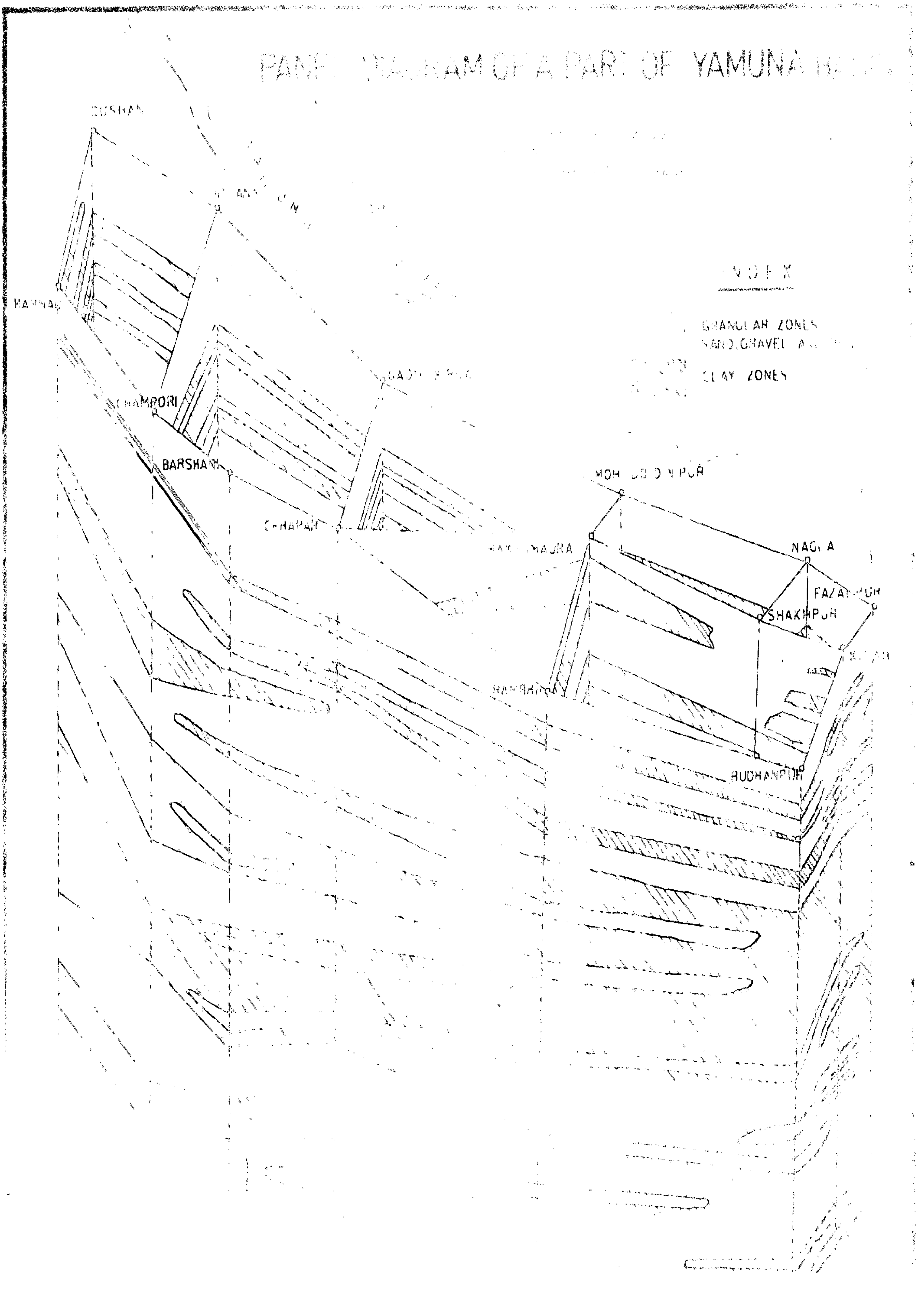
BUDHANPUR


YAMUNA
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BARSHAN
NAGLA
BUDHANPUR

only upto Bhabars abutting against Siwalik hills. The aquifers appear to be quite extensive in east-west direction.

The geophysical surveys conducted by the Oil and Natural Gas Commission indicate a large basement high approximately corresponding to the present water divide between Punjab rivers (Indus System) and Yamuna (Ganga system). Near Jagadhari the basement is at a depth of 2800 mt. (Ramachandra Rao, 1973).

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CHAPTER - 3

GROUND WATER CONDITIONS

3.1 Type of Aquifers

As discussed earlier the aquifers are thick and extensive in the north and central part of the modelled area and pinch out southward.The northerly extension of aquifers abuts against the Siwalik hills. As is evident from the panel diagram the aquifers are intercalated with the clay beds(which may or may not be very extensive). Ground water in shallow aquifers occur under water table conditions. The analysis of data of pumping tests conducted on the exploratory wells suggests that the deeper aquifers are under leaky confined conditions. However, on a regional scale the aquifers appear to be interconnected.

3.2 Aquifer characteristics

To ascertain the subsurface geology and evaluate ~~equk~~ aquifer parameters of this part of the basin H.S.M.I.T.C. had drilled fifteen boreholes out of which seven boreholes were tested for determining the aquifer characteristics. The wells were subjected to long duration pumping tests.The aquifer characteristics determined from these tests are given in Table 3.1. These aquifer parameters were utilised in designing the present analog model.

TABLE - 3.1

Location of tested wells	Transmissivity (m^2/ day)	Storavity
Dusam	2320	.00264
Harnaul	2890	.0143
Barsami	2440	.002
Garhibirbal	3240	.00555
Makhumazia	2285	.00375
Nagla	1085	.00109
Kutail	1159	.00071

From the perusal of table 3.1, it appears that the transmissivity value of aquifer is high in the northern and central part of the area and the value decreases southward.

3.3 Ground Water Recharge

The main source of recharge is through direct precipitation falling over the area and subsurface flow from adjoining parts. Run-off coming down from the siwalik hills recharges the porous and permeable Bhabar formations. Although the Bhabars do not form extensive aquifers by themselves, however it can accommodate appreciable amount of ground water which in due course of time recharges the alluvial aquifer of the Indo-Gangetic plain towards south. Another important source of recharge to ground water body is seepage from the unlined canal net work. The area has high irrigation intensity and an appreciable portion of it joins ground water body. On the basis of tritium injection survey conducted in the area, it is estimated that about 20% of rainfall is added to the ground water reservoir (Datta et.al., 1973).

3.4 Ground Water Draft

Tubewell irrigation in this part of the basin was started in the early thirties. The water table was shallow in the western part of the basin and at places water logged conditions existed. The then Punjab Govt. installed 256 augmentation tubewells (in the depth range of 90 m to 120m) along the western Yamuna canal and 150 direct irrigation tubewells were constructed in the area of study between 1953-1959. The tubewells were installed to augment the discharge of western Yamuna canal and relieve the area of water logging problem.

With the increasing food production groundwater development also increased which maintained a steady rate of development. After the introduction of high yielding crops, tubewell irrigation has provided the main sustenance to the green revolution and the rise in number of tube wells has been phenomenonal. Earlier system and their relationship is the most important controlling factor in understanding and interpreting the ground water level data.

To get a regional picture of ground water, water level contour maps were prepared for pre and post augmentation canal periods. The water level contours are based on the well inventary data collected by the various state agencies. Since the augmentation canal wells were commissioned in December 1972, the water level contour map was prepared for June 1971. Similarly to study the behaviour of water levels after the commissioning of augmentation wells, a water level contour map for June 1974 was also prepared. The description of these maps is given below:

3.5.1 Water Level contour map for June 1971

The study of June 1971 water level contours indicates that the general water table slope is from north to south with south east and south westward variations. A ground water ridge is noticed along the western Yamuna canal and another along the eastern Yamuna canal which may be attributed to the regular seepage from these unlined canals. A ground water trough exists between the Yamuna river and augmentation canal. The ground water trough is parallel to Yamuna and is located at a distance of about five kilometre westward.

the open wells fitted with 'Motes' or persian wheel were in use. Gradually some of these open wells were fitted with pump sets replacing 'Motes' and persian wheels. At places bored wells were constructed and with the greater demand of ground water, design of bored wells also improved. Today a good number of shallow tubewells tapping water table aquifer are owned by individual farmers. In recent years a large number of direct irrigation and augmentation tubewells have been constructed by the Govt. of Haryana.

In assessing the ground water draft of this part of the basin, increased ground water utilisation for domestic and industrial use was also taken into consideration. The ground water draft from the basin for the period 1967 to 1974 is given in Plate VIII. A perusal of Plate VIII indicate that total ground water draft from the basin was 17058 hectare metre in 1967-68 which increased to 95836 hectare metres in the year 1973-74.

3.5 <u>Water level Contour maps</u>

In the study of ground water regimen the observation of water levels and study of their behaviour in time and space are of basic importance. However, the study of water levels of such a thick alluvial formation having complex geohydrological conditions has its own limitations. The configuration of various aquifer system and their relationship is the most important controlling factor in understanding and interpreting the ground water level data.

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PLATE VI

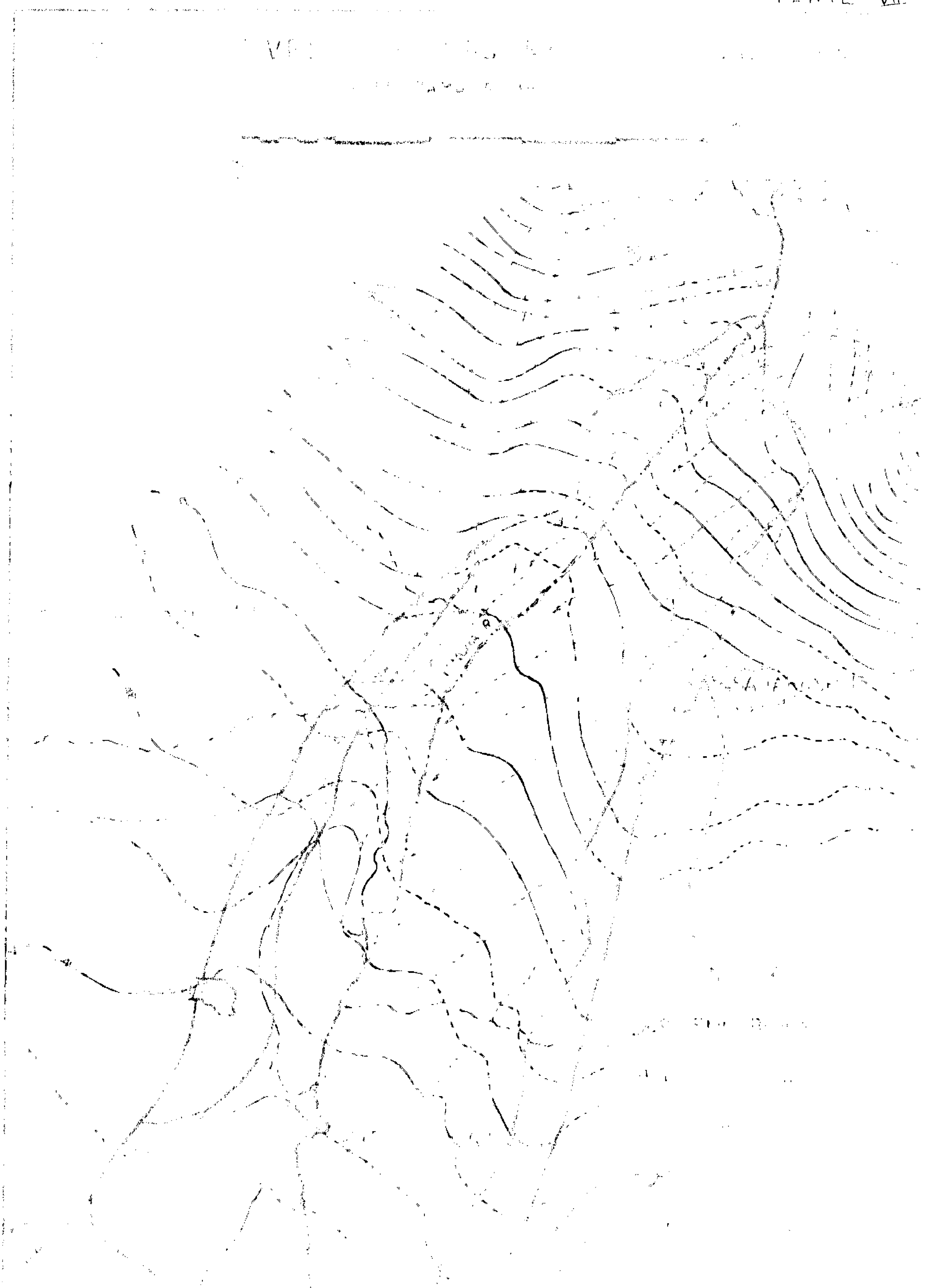
The study of flow lines indicate that from the foot hills down to latitude 30° 04'(Jatlana) river Yamuna is of effluent nature on both the sides. The flow lines also indicate that between Jatlana and latitude 29°50' the river Yamuna is effluent along the eastern side and has a influent nature along its western bank. Further southward the above relation is reversed i.e. the river acquires influent character along the eastern bank and effluent character along the western bank.

It appears that the ground water trough all through lies within the meander belt of the river and may be following the da abandoned course of river Yamuna.

3.5.2 Water level contour map for June 1974

A water level contour map for June 1974 was also prepared. By comparing the map of June 1974 with that of June 1971.it appears that although the regional behaviour is similar in June 1974, the water level contours have generally shifted upward and the ground water trough west of Yamuna has shifted further westward towards the augmentation well line. This shift is distinct on the west of river Yamuna between latitudes 29°55' and 29°30'.The shifts may be attributed to the continuous lowering of water levels in this area from June 1971 to June 1974.

PLATE VII



As noticed from June 1971 contour map river reach was effluent from both sides upto Jatlana (30° 04';77°16'). However, by June 1974 the ground water conditions changed and the reach from Jatlana to latitude 30°12' became influent along the west bank, which otherwise was effluent in June 1971. This indicates that in this reach where the ground water was contributing to river flow earlier, now the river is loosing to ground water body. This may be due to increased ground water pumpage from this part of the basin.

3.5.3. Water level fluctuations

A comparison of the above two water level maps shows that there has been a net decline in the ground water levels. The decline is more promounced in the area where augmentation wells are located, particularly the central part where the discharge from the wells is maximum. Analysing the water levels of 1971 and 1974, it was observed that there is a general decline of water levels with an average value of about one metre during this period.

To study progressive change in water levels in the modelled area since June 1967, water level data from various state government agencies were collected. The data was computed to calculate the progressive rise and fall in the water levels in the area of study between the preceeding and succeeding June months, beginning from June 1967(Table 3.1). From the rise and fall the net recharge to the aquifers can also be calculated if the total saturated volume and specific yield of the aquifer are known.

TABLE 3.1

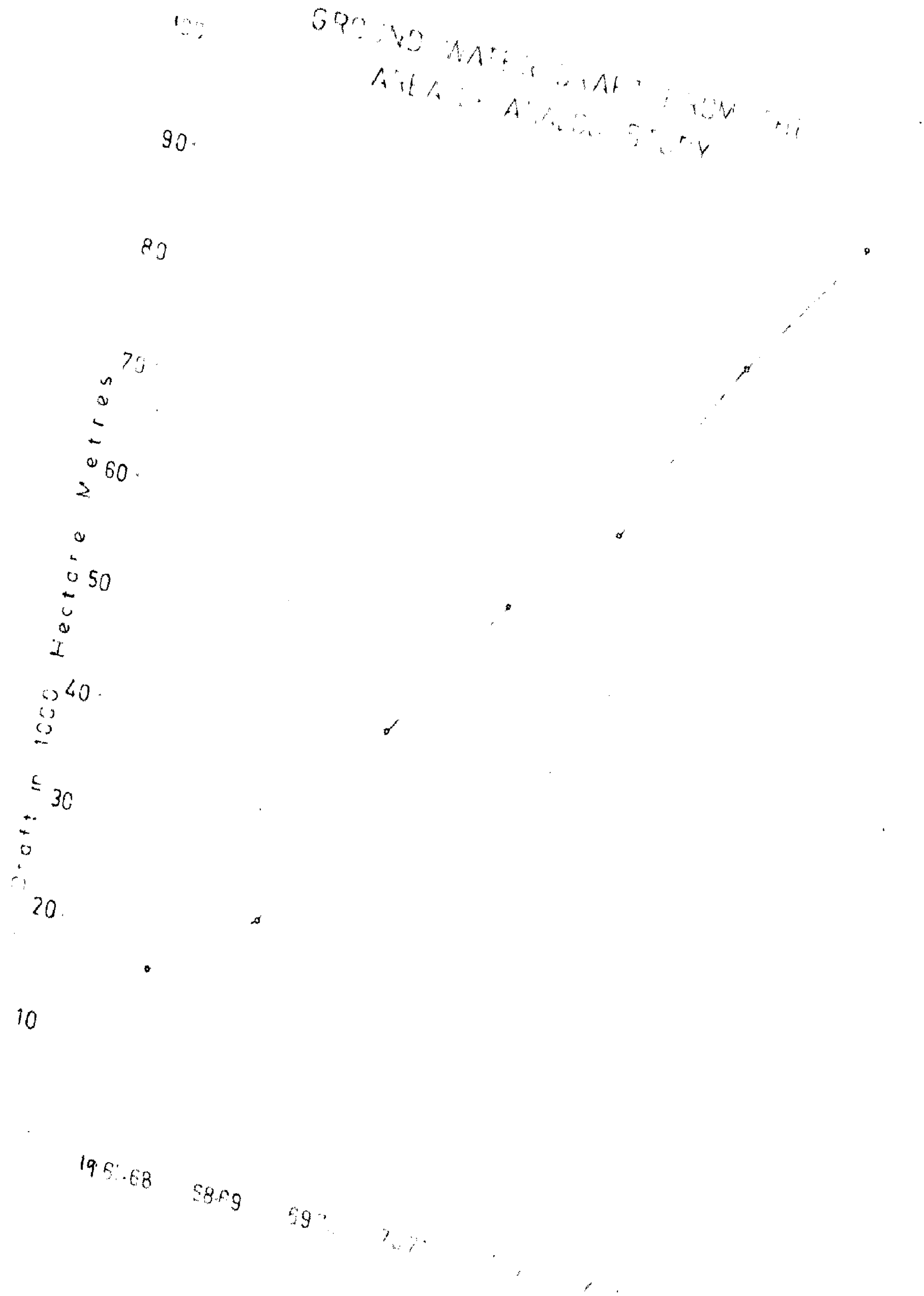
PROGRESSIVE CHANGE IN WATER LEVELS

(June over June) ∞

Year	Average rise/fall in m.	Cumulative rise/fall in m. since 1967
1967-68	+ 0.048	+ 0.048
1968-69	- 0.329	- 0.281
1969-70	- 0.0.57	- 0.338
1970-71	- 0. 045	- 0.383
1971-72	- 0.302	- 0.685
1972-73	- 0.120	- 0.805
1973-74	- 0.397	- 1.04

∞ based on arithmatic means

PLATE VIII



CHAPTER - 4

ANALYSIS OF THE HYDROGEOLOGICAL SYSTEM BY ELECTRICAL ANALOG MODEL

4.1 Purpose and scope of investigation

As evident from the foregoing discussion in the previous chapters the upper Yamuna basin is a vast alluvial plain having a rich ground water potential. The ground water from the basin has been tapped for agriculture, domestic and industrial use since historical times. However, with the thrust on grow more food campain the draft from the basin kept on increasing at a fast rate. Haryana State constructed a lined augmentation canal envisaging withdrawal of 14 cumecs(5000 cusecs) of ground water from this part of the basin apart from saving another 14 cumecs from seepage loss. The purpose of this study was to collect the necessary hydrological data and aquifer parameters, to design and construct an electrical analog model(R-C net work) that would simulate the hydrogeological conditions of this part of the basin. Excellent account of theory and practice of analog modelling is given by various workers in this field(Skibitzke 1963, Walton and Prickett, 1963).

The analog model of a part of upper Yamuna basin designed and constructed electrically duplicated the hydrgeological parameters of upper Yamuna basin. The data used in the construction of model included storavity, transmissivity and the stipulated discharge of the augmentation well. Once the analogy between hydrogeological and electrical systems was established it was possible to simulate the desired discharge and observe the effect of pumping with time on the ground water levels.

4.2 Analogy between Ground water flow and Electrical flow

It is observed that a number of physical phenomenon in nature are analogous to each other and their behaviour is governed by the diffusion equation ($\nabla^2\phi = D\frac{\partial\phi}{\partial t}$). For example the differential equation $\nabla^2 u = k\frac{\partial u}{\partial t}$ defines a host of diverse phenomenon ranging from heat flow, electromagnetic field in conductor, consolidation of soil underpressure and damped vibration etc. Similarly ground water flow in porous media is found to be wholly analogous to ohm's law governing the flow of electrical current through a conducting media. The use of this direct analogy simplifies solving the ground water problem, because hydrogeologica parameters can directly be converted to electrical equivalent by scale of model. If the hydrogeological parameters are converted to electrical parameters, the hydrological conditions of the modelled area can be simulated. Thus, the simulation of hydrological condition solves a host of problems connected with the aquifers management, which otherwise would have been difficult to compute.

The most important advantage of such models apart from being a scaled down lab. model is that time is also scaled down. With this scale down models, it may be possible to predict response of aquifers to added pumpage with time. Thus with the increasing ground water utilisation, compelling the optimisation of an aquifer system such model studies have become inevitable part of any ground water investigation.

Comparing the analogy in most general form, partial differential equiation describing unsteady confined ground water flow through porous media in three dimensional form is

$$\frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial y^2} + \frac{\partial^2 h}{\partial z^2} = \frac{S}{T}\frac{\partial h}{\partial t} \qquad 4.1$$

where S = Storavity

T = Transmissivity

h = hydraulic head

t = time

Similar equation in three dimensional form for flow of electricity in a Resistance Capacitance net work is given by

$$\frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} + \frac{\partial^2 V}{\partial z^2} = RC\frac{\partial V}{\partial t} \qquad 4.2$$

Where R = Resistance

C = Capacitance

V = Voltage

t = time

Considering the flow to be two dimensional the equation (1) reduces to

$$\frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial y^2} = \frac{S}{T}\frac{\partial h}{\partial t} \qquad 4.3$$

and equation(4.2) reduces to

$$\frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} = RC\frac{\partial V}{\partial t} \qquad 4.4$$

If the aquifer system is descretised into a finite difference form and divided into a grid of equal spacing, such that flow elements for width a is represented by vector volume, the differential equation(4.3) reduces to

$$\frac{h_1 + H_2 + H_3 + h_4 - 4h_o}{a^2} = \frac{S}{T}\frac{h}{t} \qquad 4.5$$

The flow of two dimensional electric current in a R.C.net work, can be discretised in finite difference form as

$$\frac{V_1 + V_2 + V_3 + V_4 - 4V_o}{R} = \frac{C\ V}{t} \qquad 4.6$$

The substracts 0,1,2,3,4 represent the nodal values, h_o and V_o being the values at central node.

Rewriting the equations 4.5 and 4.6

$$\text{(aquifer)} \quad h_1+h_2+h_3+h_4-4g_o = a^2 \frac{S}{T}\frac{\partial h}{\partial t} \qquad .. \quad 4.7$$

$$\text{(analogy)} \quad V_1+V_2+V_3+V_4-4V_o = RC\frac{\partial v}{\partial t} \qquad .. \quad 4.8$$

Comparing the equations(4.7) and (4.8) it would appear that h in aquifer is analogous to voltage V in model. Storavity is analogous to capacitance and resiprocal of transmissivity is analogous to Resistance. However,it appears that the product of $a^2 \frac{S}{T}$ is analogous to product of RC or $\frac{S}{T}$ is analogous to product of RC since a is constant for the model. While designing the model the product of RC was maintained according to the product of $\frac{S}{T}$. Further the analogy can be maintained by keeping constant either the value of R or C.

4.3 Scale Factor

Continuing comparison between water flow in a porous media and electric current flow in a conductor, water moves in an aquifer just as charge moves in an electric circuit.While the quantity of water is measured in cubic metres the charge is measured in coulombs. The rate of flow of water through a givenc ross section of the aquifer is expressed as cubic metres/day,the flow of electricity is expressed as coulombs/second or amperes.The hydrauli head loss between two points in an aquifer is expressed in metres, the potential drop across an electrical circuit is in volts. All these four analogous units may be connected by scale factors from units of one system to the analogous units in other system. The four scale factors K_1, K_2, K_3 and K_4 are defined as follows:

$$q \text{ (cubic metres)} = k_1 e \text{ (coulombs)} \quad .. \quad 4.9$$

$$h \text{ (metres)} = k_2 V \text{ (volts)} \quad .. \quad 4.10$$

$$Q \text{ (cubic metres/day)} = K_3 I \text{ (ampires)} \quad .. \quad 4.11$$

$$td \text{ (days)} = K_4 \, ts \text{(seconds)} \quad .. \quad 4.12$$

The relation between the conversion factors K_1, K_2, K_3 and K_4 can be established as follows. By definition

$Q = q/td$ where Q = Cubic metre/day

q = cubic metres

td = time in days

Similarly $Q = K_3 I$

$q = K_1 e$

and $td = K_4 \, tS$ and also $\frac{e}{ts} = I$

(Coulombs/second = ampires)

Substituting these values in the equation $Q = q/td$

$$K_3 T = \frac{K_1 e}{K_4 ts}$$

or

$$K_3 K_4 I = \frac{K_1 e}{ts}$$

since $\frac{e}{ts} = I$ the above relation reduces to $K_3 , K_4 = K_1$ .. 4.13

4.4 Design of electrical circuit elements

The resistance & capacitance values of analog model are cal-culated as follows:

From ohms law

$$R = \frac{V}{I}$$

however, from the equations (4.10) and (4.11)

$$V = \frac{h}{K_2} \quad \text{and } I = \frac{Q}{K_3}$$

substituting the values of V in volts and I in ampires

$$R = \frac{\frac{h}{K_2}}{\frac{Q}{K_3}} = \frac{K_3}{K_2}\frac{h}{Q}$$

$$\text{or} \quad \frac{K_3}{K_3 \; Q/h}$$

since T transmissivity is defined as cubic metres/day/metre, T, (transmissivity) may be substituted in place of Q/h

$$\text{or} \quad R = \frac{K_3}{K_2 \; T} \qquad \ldots \qquad 4.14$$

In a similar way value of capacitance may be calculated. From the coulomb's law for the electrical charge of a capacitor

$$C = \frac{e}{v}$$

where $e = \frac{q}{k_1}$ and $v = \frac{h}{k_2}$ so that

$$C = \frac{q/k_1}{h/K_2} \quad \text{or} \quad \frac{q}{h}\frac{K_2}{K_1}$$

since q/h has the dimension of L^2 which can be replaced by a^2S and computed as follows

$$C = \frac{q}{h} \frac{K_2}{K_1}$$

since $\left(\frac{q}{h}\right)^{M^3/M}$ has the dimension of L^2 which can be replaced by $(a^2,S)^{M^2}$ (also having the dimension of L^2). The conversion can be derived as follows.

$$\frac{q}{h}^{\frac{M^3}{M}} \times \frac{M^3}{M} = (a^2,S)^{M^2} \times M^2$$

$$\text{or} \left(\frac{q}{h}\right)^{\frac{M^3}{M}} = (a^2.S)^{M^2}$$

replacing q/h for $a^2.S$

$$C = a^2.s. \frac{K_2}{K_1} \qquad .. \qquad 4.15$$

where a is expressed in metres and C in farads because e is expressed in coulombs and V in volts.

4.5 Simulation of boundaries

Whenever the analog model net work does not coincide with the aquifer boundaries, it becomes necessary to simulate such boundaries by adjusting the values of resistors and capacitors accordingly. A barrier boundary across which there is no flow can be simulated by an open circuit, a boundary of constant head may be simulated by terminating and short circuiting the corresponding parts of the analog net work. A boundary where the head along the boundary is proportional to its normal derivative along that boundary may be duplicated by connecting resistors between the nodes along the boundary and grounding them. The irregular shaped boundaries are simulated with the help of the vector volume technique whereby the resistors and capacitor values are modified to suit the corresponding aquifer parameters. The following equation may be used to compute values of resistors adjusted to the boundaries.

$$R_x = R_b \frac{\Delta x}{\Delta y} \qquad .. \qquad 4.16$$

$$R_y = R_b \frac{\Delta y}{\Delta x} \qquad .. \qquad 4.17$$

where R_x is the resistance in x direction and R_y is the resistance in the y direction adjacent to the boundary. R_b is the value of resistor near the boundary, which otherwise would have been adopted had the boundary been regular. Δx is the portion of aquifer represented by resistor in x direction in metres and Δy is the portion of aquifer represented by resistor in y direction in metres.

The capacitance of the capacitor may be computed to suit the irregular boundary by modifying the area since the magnitude of the capacitors is directly proportional to the vector area of the portion of aquifer they represent. The values of capacitors adjacent to the boundaries may be computed by the following equation:

$$Cb = Av.\ S.\ \frac{K_2}{K_1} \qquad .. \qquad 4.18$$

where Av is the vector area of the aquifer to be represented by the capacitors in square metres.

4.6. Simulation of Radius of pumping well

When a pumping well is being simulated at a junction of an analog model its radius will be

$$rw = \frac{a}{4.81}$$

where rw is the radius of the production well in metres and a is grid spacing in metres. If fully penetrating pumping well of a particular radius is to be simulated, additional resistor Rw calculated from the formula

$$Rw = \frac{K_3}{K_2 T}\ 0.3665\ \log\left(\frac{a}{4.81\ RW}\right)$$

will have to be introduced at the junction. The effects of partial penetration well losses and gravel packs if needed can also be simulated (Prickett, 1967).

4.7 Simulation of recovery of evapotranspiration

In the ground water budgeting problems it is observed that when the water table aquifers are pumped,due to lowering of water table there is a considerable recovery of ground water which would have been lost by evapotranspiration,particularly when the water table is very shallow. The salvaging of the evapotransperation loss can be simulated with introduction of a diode bank in the circuit (Skibitzke 1963).

4.8 Simulation of Aquifer of Infinite extent by application of conformal mapping

The normal practice of simulating an aquifer of finite extent has its own limitations. The boundaries of the aquifer to be so simulated are decided on the basis of convenience rather than scientific consideration. This limitation is more applicable in case of extensive aquifers as that of Upper Yamuna Basin.The usual practice is to simulate the area of more influence and significance with fine grid and adjoining part of lesser influence and significance with coarse grid.However,with this practice it may be possible to simulate only a limited convenient area. The aquifer boundaries in an analog model are taken as some hydrological boundaries,but if these hydrological boundaries may not be stable with time or when quite large area is to be modelled the analog modelling becomes combersome. To overcome this difficulty conformal mapping approach has been made (Rastogi 1973). With conformal mapping area of infinite extent can be mathematically mapped within finite limits. Mathematically the area of inifnite extent can be mapped inside a finite circle of radius R by the relation

$$W = \frac{R^2}{Z} \qquad \ldots \qquad 4.19$$

This is a transformation for mapping the outside area of a circle of radius R and vice-versa. Z and W being the coordinates of points in xy and Uv planes respectively. The points Z and W are complex numbers which can be defined as

$$Z = x + iy \qquad \ldots \qquad 4.20$$

$$W = U + iv \qquad \ldots \qquad 4.21$$

where x,y and U,v are the coordinates of point z in xy plane and of point w in Uv plane respectively. Substituting the values of Z and W in the equation

$$Z = \frac{R^2}{W}$$

$$x+iy = \frac{R^2}{u+iv}$$

$$x+iy = \frac{R^2 (u - iv)}{u^2+v^2}$$

separating real and imaginary parts

$$x = \frac{R^2 u}{4u^2+v^2} \qquad \ldots \qquad 4.22$$

$$y = \frac{R^2 v}{u^2+v^2} \qquad \ldots 4.23$$

or
$$u = \frac{R^2 x}{x^2+y^2} \qquad \ldots 4.24$$

$$v = -\frac{R^2 y}{x^2+y^2} \qquad \ldots 4.25$$

from these relations a point outside a circle of radius R can be mapped inside a circle of same radius or vice-versa. The differential equation governing two dimensional ground water flow in homogeneous isotropic porous media in z plane

$$\frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial y^2} = \frac{S}{T} \cdot \frac{\partial h}{\partial t} \qquad \ldots$$

changes to (in w plane)

$$\frac{\partial^2 h}{\partial u^2} + \frac{\partial^2 h}{\partial v^2} = \frac{(x^2+y^2)^2}{R^4} \frac{S}{T} \frac{\partial h}{\partial t} \qquad \ldots 4.26$$

or
$$-\frac{S}{T} \quad \frac{R^4}{(u^2+v^2)^2} \quad \frac{\partial h}{\partial t} \qquad \ldots 4.27$$

The equation implies that in the process of transforming the point outside the circle in xy plane to inside the circle in uv plane the ratio S/T is changed by

$$\frac{R^4}{(u^2+v^2)^2}$$

Let $\frac{S}{T}$ be α and $\frac{(x^2+y^2)^2}{R^4} \quad \frac{S}{T} = \beta$

The equation (4.26) may be rewritten as

$$\frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial y^2} = \beta \frac{\partial h}{\partial t} \qquad \ldots 4.28$$

The equation(4.28) implies that the value of α is changed to β in the process of conformal mapping of a point in Z plane to w plane.

Here for applying conformal mapping two circles of same diameter may be taken and the grid spacing in both the circle taken as a, one of the circle represents the main area in Z plan and another the conformably mapped area of study. All the nodes in w plane can be transformed and their coordinates found in Z plane or vice-versa. For the nodes of main area values of α $\left(\frac{S}{T}\right)$ can be calculated at each node, similarly for the transformed node values of β $\left[= \frac{x^2+y^2}{R^4} \frac{S}{T}\right]$ can be computed for each transformed node. Further keeping the values of resistors constant the changed values of the capacitors can be computed for α and β

The values of resistors and capacitors can be calculated by the equation(4.14) and (4.15).

$$R = \frac{K^3}{K_2 T}$$

$$C = a^2 \; S \; \frac{K_2}{K_1} \quad \text{(in metric system)}$$

Thus for the calculated values of R and C the values of capacitors can be modified for the constant Resistance, keeping ratio of $\frac{S}{T}$ equal to the product of RC for the constant values of R.

The values of RC for the transformed values of α can be calculated as follows

$$\alpha = \frac{S}{T} = KRC \quad \text{where K is a constant.}$$

$$\beta = \frac{(x^2+y^2)^2}{R^4} \frac{S}{T} \quad \text{or} \quad \frac{R^4}{(u^2+v^2)^2} \frac{S}{T}$$

For all the nodes, values of β may be calculated, for the constant values of Resistor modified value of capacitor may be calculated. The values of capacitor calculated for the conformably mapped area are given in Appendix -B.

CHAPTER-5

ELECTRICAL ANALOG MODEL OF A PART OF UPPER YAMUNA BASIN

5.1 Designing of the model

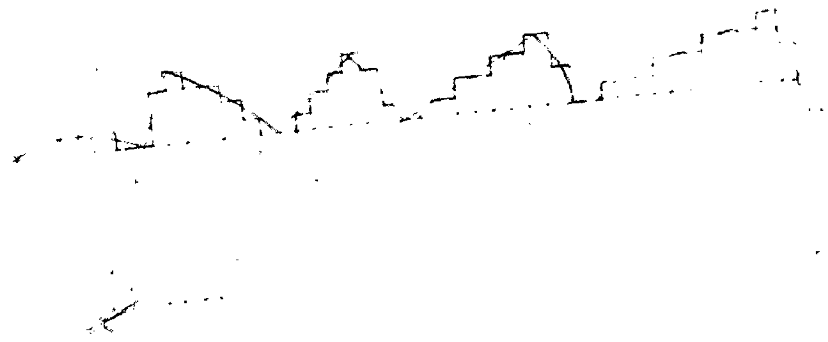
The R.C. analog model of a part of Upper Yamuna basin covering an area of 2570 sq.km in parts of Ambala, Kurukshetra and Karnal districts of Haryana and Saharanpur and Muzzaffar-nagar districts of U.P. was designed and developed on the basis of geohydrological data available upto 1974.

As discussed earlier in this part of the basin ground water development was encouraged in early fiftees to relieve the area of water logging problem. However, with the increasing ground water exploitation it is feared that further development may adversely effect the ground water conditions by causing over-draft. The Government of Haryana has installed a battery of additional tubewells for augmenting the lean period supply of Western Yamuna Canal. To study the effect of this additional draft on the water levels and to study the drawdown component due to this increased draft present R.C. analog model was developed.

The analog model was developed on the basis of hydrogeo-logical parameters collected by Haryana State Minor Irrigation Tubewell Corporation during the exploration for constructing

... MAPPING TO A RECTANGULAR AREA

SCALE ...



... the Area into ... Segments

PLATE

the augmentation tubewells. In all fifteen exploratory boreholes were drilled which were converted to production wells. Long duration pumping tests were carried out on seven wells. The test data were analysed and values of transmissivity and storaity were computed. The transmissivity and storavity values thus obtained (Table 3.1) have been used in designing the analog model.

As it is evident from the panel diagram(Plate V) and the values of storavity and transmissivity, productive aquifers in the area are hetrogeneous and anisotropic. Distribution of capacitors and resistors in the analog model has been decided on the basis of aquifer geometry and their hydrological characteristics.

As discussed earlier conformal mapping technique was also applied in the present study. The conformal mapping technique envisages mappihg an area of infinite extent into a finite extent, (eq.4.19). Since the area of present study was rectangular in shape, for applying conformal mapping it was divided into segments of circles(Plate IX). For each segment the outside area of the circle segment was mapped inside the segment of the circle of same radius. The area was divided into total five circle segment. The radius of each circle segment being 51.2 km, 36.5 km, 25.9 km, 19.3 km and 13.7 km respectively.

In all the circle segments the point outside the segment of circle was mapped inside the segment of circle in another plane. Now if the boundary points of one circle segment in one plane are connected with the identical boundary points of the circle in another plane, the area of inifite extent can be mapped into finite extent. However, in the present model barrier boundaries were assumed in the north and south as the aquifers are bounded by the siwalik formations in the north and they are pinching out in the south. The area beyond these barrier boundaries has not been mapped and left with an open circuit in the analog model. The various node points are given in Plate XIII. The identical nodes of main area and the corresponding nodes in the conformably mapped area are given in Appendix-B.

5.2 Scale Factors

Based on geohydrological conditions and the available instruments the following scale factors were selected.

$K_1 = 4.60 \times 10^{11}$ cu.mt/couloumb

$K_2 = 1$ mt/volt

$K_3 = 3.785 \times 10^{7}$ Cu mt/day/amp

$K_4 = 12.16 \times 10^{3}$ days/sec.

With the available map(1:633360) and the problem in hand grid spcacing of 2 cm = 1267.2 mt was adopted to minimise the finite difference approximation.

5.3 Construction of Analog Model

The analog model was constructed by using two 4 mm thick bakelite sheets of .9 x 1.2 mt size, final model assembly being

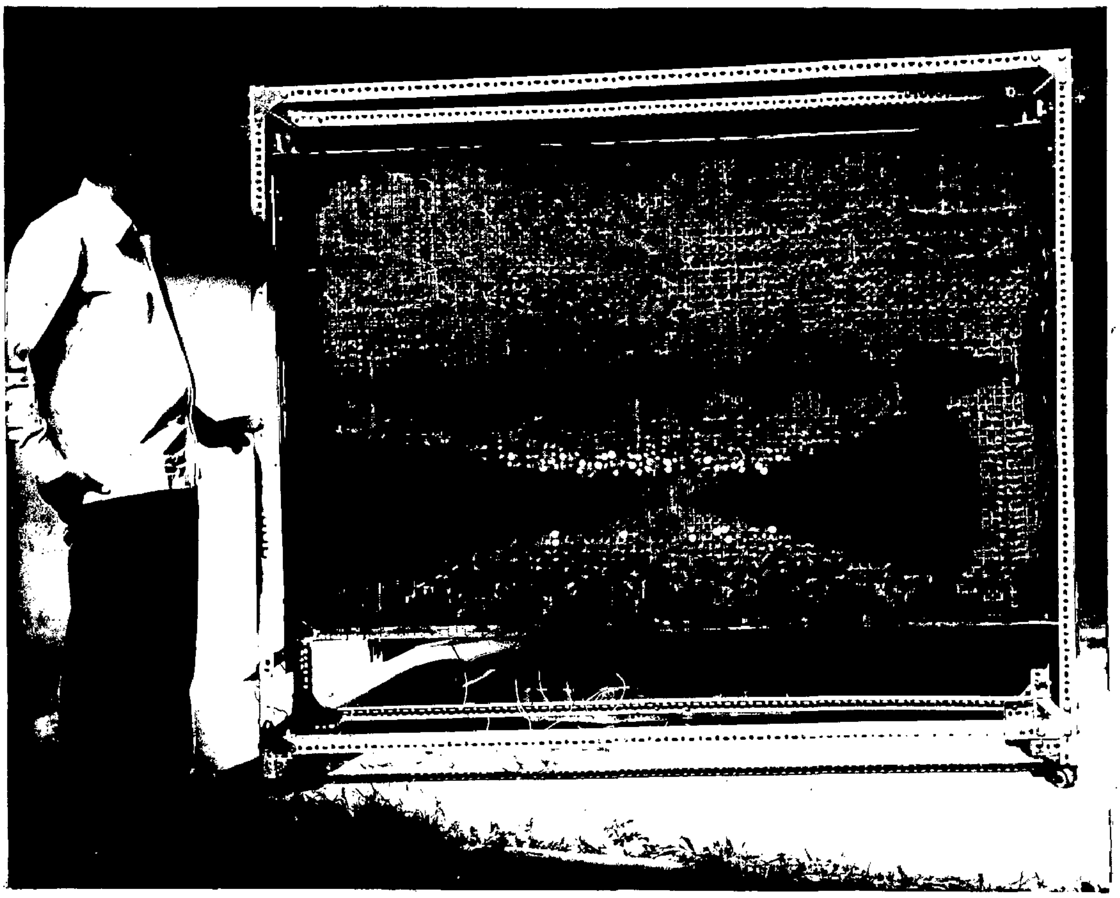
Photograph-1: Nodal arrangement showing the alignment of augmentation canal and pumping points.

of 1.8 x 2.4 mt. A map(1:63360) of the area was superimposed on the bakelite sheets. Holes in a grid pattern of 2 cm were, drilled in the bakelite sheet in which 3 mm thick brass pins were inserted for easy connection of the resistors and capacitors. The whole assembly was mounted on a stand with rollers for the easy mobility of model(photograph 1). Brass plates were mounted on two sides of the assembly and wires stretched across brass plates for easy grounding of capacitors(photograph-2).

The values of capacitors and resistors were calculated for each node according to the areal distribution of transmissivity and storavity. However, as the values of resistors was kept constant i.e. 33 ohms the values of capacitors at each node were adjusted according to the product of RC. The values of capacitors calcualted are given in Appendix-B. As shown in plate XIII four resistors of 33 ohms and one capacitor were connected to each node. All the capacitors were grounded.

For conformably mapped area the value of RC was modified by $\frac{R^4}{(x^2+y^2)^2}$ or $\frac{(u^2+v^2)^2}{R^4}$ to account for the increased area, obviously the change was only in the values of capacitors since the value of resistors was kept constant.

The values of capacitors calculated for the conformably mapped area change abruptly from one segment of circle to segment of another circle which effects the simulation adversely.



Photograph-2: A view of the analog model showing the R-C net work.

This abrupt change is because of change in the radius of circle segments. The error can be minimised by dividing the area into larger numbers of circle segments. For the conformably mapped area uniform values of storavity and transmissivity were assumed for each extension of the main area. The adopted values of storavity and transmissivity are given in table 5.1.

TABLE 5-1.

Extension of the main area (Refer plate XIII)	Storavity	Transmissivity
A1-A15:B1-342	.00229	2520
A1-A15:B43-B83	.00114	1514
A16-A29:B1-B42	.00429	2520
A16-A29:B43-B83	.00429	1514

Wherever the boundaries of the modelled area did not coincide with the grid, the values of resistors and capacitors have been calculated according to the equations 4.16 and 4.17. The values of the capacitors were computed for the 33kohms constant value of resistor. The area of study has been simulated upto infinity by connecting the identical points of the main area with the conformably mapped area. The boundary points connected are given in Appendix-A. A total of 6288 carbon resistors of 33 K ohms value and of 1/2 wattage with 10% tolerance and 3290 ceramic capacitor of 1/2 wattage and 10% tolerance were used in the construction of the analog model.

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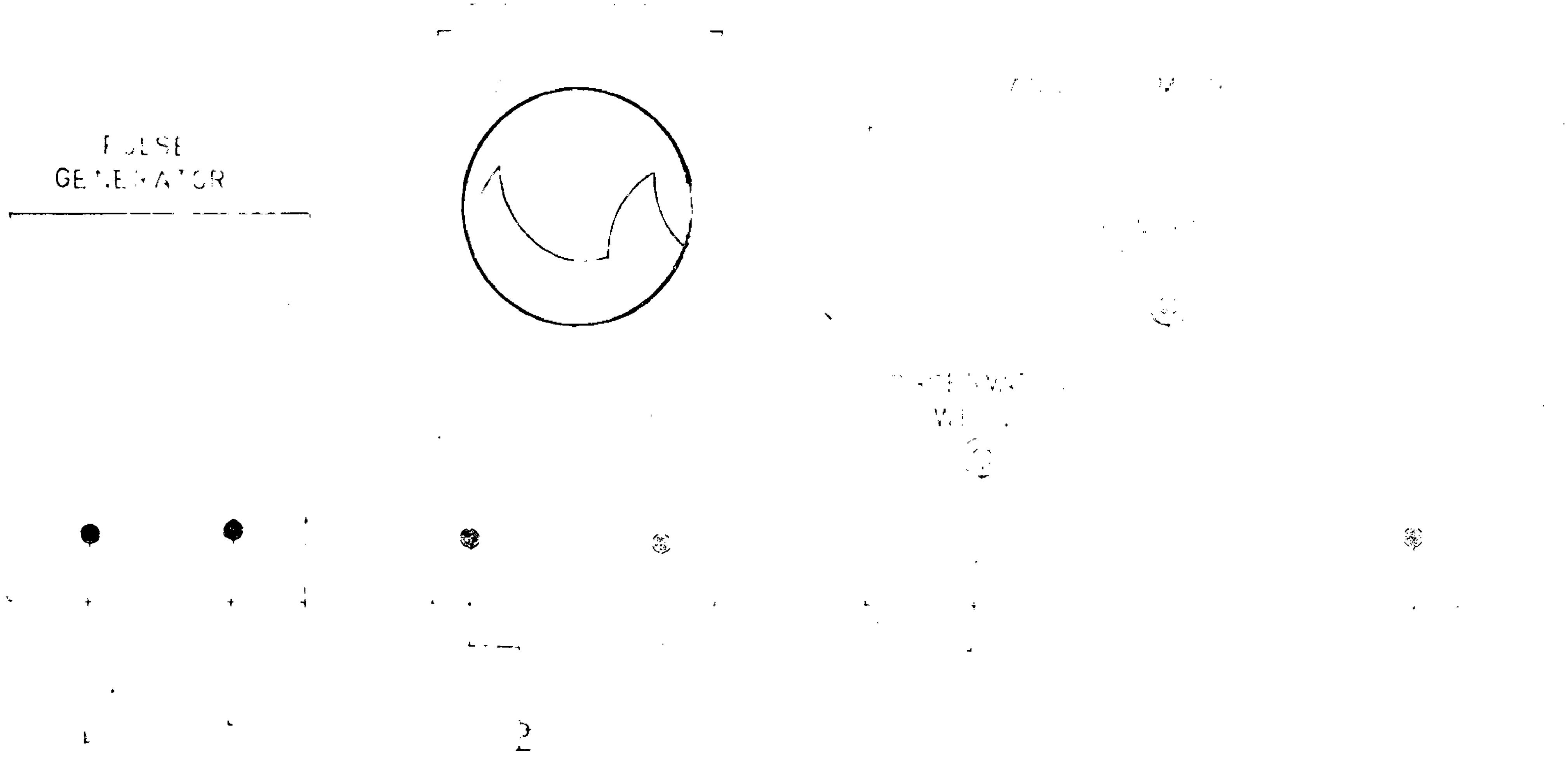


EXPERIMENTAL SET UP OF ANALOG EXCITION RESPONSE APPARATUS

PLATE X

CHAPTER - 6

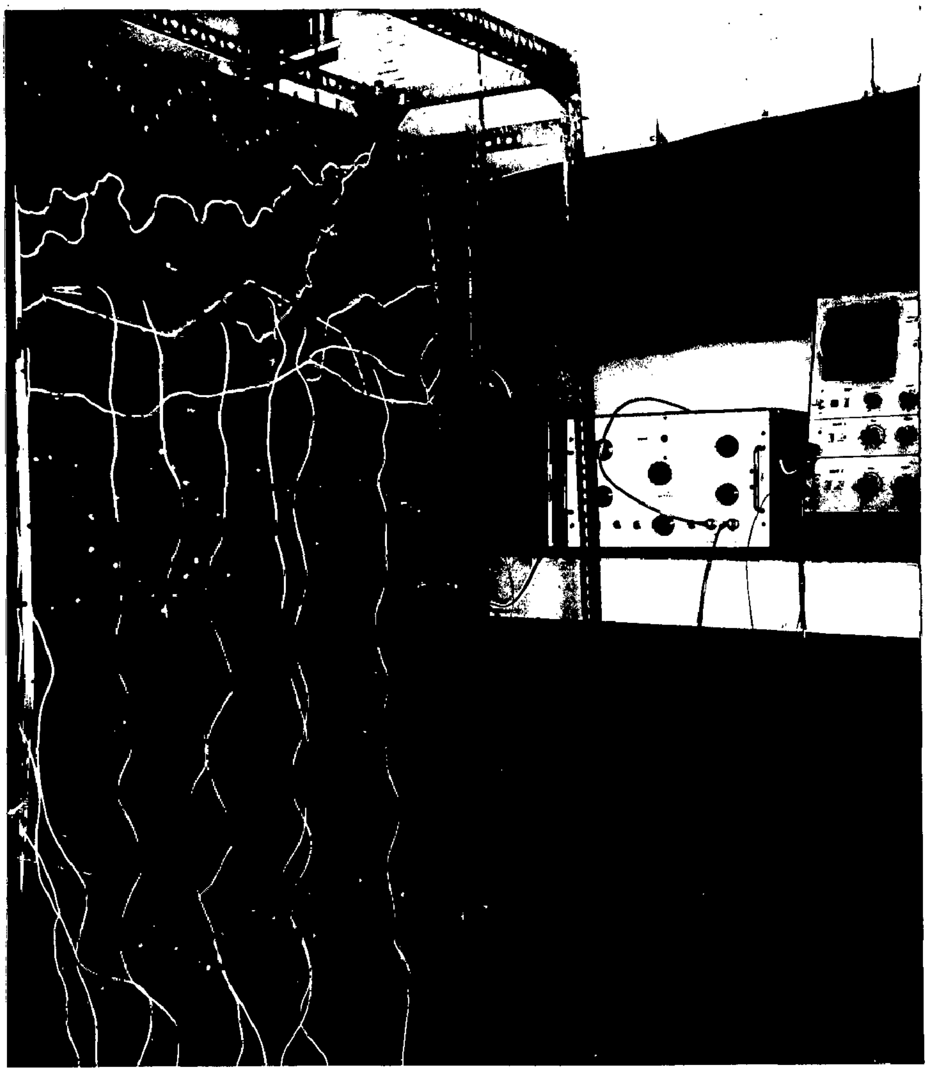
EXPERIMENTAL SET-UP

6.1 Excitation response apparatus

The analog model assembly should be tested to verify the validity of simulation of actual ground water conditions. The model when given a step voltage input at a node simulates actual rate of pumping. The results of excitation can be observed on the oscilloscope screen by putting probes at different nodes simulating observation wells. The time - voltage drop curve thus simulates time drawdown curve. The values of time voltage drop can be transformed into time - water head curve by the scale of factors already adopted. The time drawdown curve thus obtained for a current input should simulate the drawdown for corresponding ground water discharge. The experimental set up of the excitation response apparatus is given in the Plate X. The excitation response apparatus required in the analog model study are power supply, pulse generation and oscilloscope (photograph 3).

6.1-1 Pulse Generator

The pulse generator gives a rectangular shaped pulse of different width and amplitude. When the pulse is fed to the model it simulates discharge and duration of pumping (a negative pulse simulates pumping and a positive pulse simulates recharging).



Photograph 3: Excitation Response set up

6.1.2 Oscilloscope

The oscilloscope measures the response of the pumping at observation nodes in the form of time-voltage drop curve. The time-voltage drop curve can be converted to time drawn down curve. In analog studies a double channel oscilloscope is required. The double channel oscilloscope will be helpful in comparison of the pulse being fed to the pumping node and the response of the pulse observed at the observation node. Further to calibrate the discharge voltage can be measured across the calibrating resistors for giving the required input current to simulate the desired discharge.

6.2 Testing of the Model

The accuracy of the model depends on the hydrogeological parameters and the components used in the assembly of the model. The model can be subjected to calibration by comparing the analytical and analog results, once the model has been calibrated different complex hydrological boundaries and pumping schemes can be simulated (Walton and Prickett,1963,Anderson 1972).

In order to test the model arbitrary discharges were simulated at five pumping nodes and the time-voltage drop curves were observed in the vicinity of pumping nodes to determine the effect of pumping on water levels. The time voltage curve of analog model thus obtained may be converted to time drawdown records. The time drawdown curve were calculated analytically also for simulated discharge and is compared with the analog results. The analog and analytical results are given in Plate XI. On comparing the analog and analytical values it is evident that both the data are matching satisfactorily.

6.3 Effects of the Augmentation wells

After the verification of the model the discharge of the augmentation wells was also simulated by connecting the nodes as given in Plate XII. The augmentation well line was sub-divided into different segments, the cumulative discharge of the wells in each segment was simulated by the corresponding current inputs. Simulation of different discharges in different reaches has been necessitated because of variations in well discharges. The wells in the central reach of the canal have higher discharge which decreases southward. After assigning current input to each segment accordingly, total discharge of 1097650 cu.mt/day for 121.6 days pumping period was simulated and the drawdown was observed at various observation nodes in the model. Time voltage curve for all the observation nodes was obtained and a drawdown pattern map was prepared(plate XII). A maximum drawdown of 10 metres was observed in the central and northern part of the area.

-

PLATE XII

CHAPTER -7

DISCUSSION AND CONCLUSIONS

7.1. R-C Analog Model

An electrical analog (R-C) model of a part of Upper Yamuna basin comprising parts of districts Karnal, Ambala and Kurekshetra of Haryana and Saharanpur and Muzzafarnagar districts of U.P. covering an area of 2570 sq.km was prepared. The analog model has been designed to simulate the varying geohydrological conditions. Although the pumping test results indicate that the aquifers upto 300 mt depth are underleaky confined conditions, however, from the perusal of lithologs it appears that on the regional scale the aquifers are interconnected. Therefore the area can be modelled as one single aquifer. The resistors and capacitors were calculated according to the distribution of transmissivity and storavity in the aquifer system. Resistors of 33 K ohms and capacitors of different values were used in the construction of the model. The change in the value of resistors was adjusted by changing the value of capacitors accordingly by keeping the product of RC constant.

The present analog model was developed to apply 1) To conformal mapping technique, 2) Fixed resistor/capacitor approach to actual field conditions and 3) To study the effect of augmentation wells on the water levels.

7.2 Conformal mapping

Conformal mapping technique can be conveniently applied to analog modelling for ground water studies. The approach will be helpful in modelling a large area, particularly when a specific area with out side area of large extent has to be modelled.

Since the area of present study is of rectangular shape, it was divided into segment of circles for conformal mapping, while dividing the area into segment of circle and calculating the values of capacitors for conformably mapped area. The value of capacitors changes abruptly from one segment of circle to another segment. This effected the simulation adversely. To minimise this error the area could be divided into larger number of circle segments.

7.3 Constant Resistors/Capacitors

Values of either the resistors or capacitors may be kept constant and the change in transmissivity and storavity may be adjusted accordingly. However, it is advisable to keep the value of resistors constant and change the capacitors. If in future the model is to be modified on the basis of additional hydrogeological data and changed hydrological conditions it would be more convenient to replace a capacitor.

Further in a R-C net work the number of resistors is invariably more than double as compared with the number of capacitors.

7.4 Verification of the model

In order to test the model arbitrary discharges were simulated and the drawdown was observed at various observation nodes. The drawdowns were also calculated analytically for the simulated discharge. It was found that analog and analytical results match satisfactorily.

7.5 Effects of Augmentation wells

The effect of the augmentation wells on groundwater levels was also studied. The discharge of 1097650 cu.mt/day for 121.6 days pumping was simulated and the drawdown was observed at various nodes. Since the discharge of augmentation wells is more in the central and northern parts of the area, maximum drawdown of 10 metres was observed in these parts. As the augmentation wells are located along the canal in a line the cone of depression observed is elliptical in shape. The noticable effect of this pumpage is observed as far as 25 km in the east and 18 km in the west.

7.6 Limitations of the present model

The model was designed on the limited hydrogeological data available for a vast alluvial thickness of Upper Yamuna basin. Only few values of aquifer parameters and the limited information about aquifer geometry was available in designing the model.

7.7 Recommendations for future work

Further studies with the model may be continued by simulating actual water levels in the area and imposing hydrological boundaries like western Yamuna Canal and river Yamuna.. The effect of change in river stage could also be simulated. Simulation of different pumping scheme and varying recharge to aquifers will help in the management of aquifers of this part of the basin.

APPENDIX-A

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APPENDIX-A

COMMON BOUNDARY NODES OF THE MAIN AREA AND CONFORMABLY MAPPED AREA OF STUDY

(The nodal arrangement is given in Plate XXII)

1			2		
NODE OF MAIN AREA	Connected to	NODE OF CONFORMABLY MAPPED AREA	NODE OF MAIN AREA	Connected to	NODE OF CONFORMABLY MAPP AREA
A7,B1		A52, B1	A8,B1		A51,B1
A9,B1		A50,B1	A10,B1		A49,B1
A11,B1		A48,B1	A12,B1		A47,B1
A13,B1		A46,B1	A14,B1		A45,B1
A15,B1		A44,B1	A16,B1		A43,B1
A17,B1		A42,B1	A18,B1		A41,B1
A19,B1		A40,B1	A20,B1		A39,B1
A21,B1		A38,B1	A22,B1		A37,B1
A23,B1		A36,B1	A23,B2		A36,B2
A24,B2		A35,B2	A25,B2		A34,B2
26,B2		A33,B2	A27,B2		A32,B2
27,B3		A32,B3	A28,B3		A31,B3
29,B3		A30,B3			
29,B4		A30,B4	A28,B4		A31,B4
28,B5		A31,B5	A28,B5		A31,B6
28,B7		A31,B7	A27,B7		A32,B7
27,B8		A32, B8	A27,B9		A32,B9
27,B10		B32,B10	A26,B10		A33,B10

Contd..

A26, B11	A33,B11	A26,B12	A33,B12
A26,B13	A33,B13	A25,B13	A34,B13
A25,B14	A34,B14	A25,B15	A34,B15
A26,B15	A33,B15	A27,B15	A32,B15
A27,B16	A32,B16	A28,B16	A31,B16
A29,B16	A30,B16	A29,B17	A30,B17
A28,B17	A31,B17	A28,B19	A31,B19
A27,B19	A32,B19	A27,B20	A32,B20
A27,B21	A32,B21	A26,B21	A33,B21
A26,B22	A33,B22	A26,B23	A33,B23
A26,B24	A33,B24	A26,B25	A33,B25
A27,B25	A32,B25	A28,B25	A3-,B25
A28,B26	A31,B26	A28,B27	A3-,B27
A28,B28	A31,B28	A27,B28	A32,B28
A27,B29	A32,B29	A26,B29	A33,B29
A26,B30	A33,B30	A25,B30	A34,B30
A25,B31	A34,B31	A25,B32	A34,B32
A26,B32	A33,B32	A26,B33	A33,B33
A27,B33	A32,B33	A28,B34	A31,B34
A28,B35	A31,B35	A28,B36	A31,B36
A29,B36	A30,B36	A29,B37	A30,B37
A28,B37	A31,B37	A28,B38	A31,B38
A27,B38	A32,B38	A26,B38	A33,B38
A25,B38	A34,B38	A25,B39	A34,B39

Contd..

A25,B40	A34,B40	A26,B40,	A33,B40
A26,B41	A33,B41	A26,B42	A33,B42
A26,B43	A33,B43	A26,B44	A33,B44
A25,B44	A34,B44	A25,B45	A34,B45
A25,B46	A34,B46	A26,B46	A33,B46
A27,B46	A32,B46	A28,B46	A31,B46
A28,B47	A31,B47	A29,B47	A30,B47
A29,B48	A30,B48	A28,B48	A31,B48
A28,B49	A31,B49	A28,B50	A31,B50
A27,B50	A32,B50	A27,B51	A32,B51
A26,B51	A33,B51	A26,B52	A33,B52
A25,B52	A34,B52	A25,B53	A34,B53
A25,B54	A34,B54	A26,B54	A33,B54
A26,B55	A33,B55	A27,B55	A32,B55
B27,B56	A32,B56	A28,B56	A31,B56
A28,B57	A31,B57	A28,B50	A31,B58
A28,B59	A31,B59	A27,B59	A32,B59
A26,B59	A33,B59	A26,B60	A33,B60
A26,B61	A33,B61	A26,B62	A33,B62
A26,B63	A33,B63	A27,B63	A32,B63
A27,B64	A32,B64	A27,B65	A32,B65
A28,B65	A31,B65	A28,B66	A31,B66
A28,B67	A31,B67	A29,B67	A30,B67
A29,B68	A30,B68	A28,B68	A31,B68
A27,B68	A32,B68	A27,B69	A32,B69

Co ntd.

A26,B69	A33,B69	A25,B69	A34,B69
A25,B70	A34,B70	A25,B71	A34,B71
A26,B71	A33,B71	A26,B72	A33,B72
A26,B73	A33,B73	A26,B74	A33,B74
A27,B74	A32,B74	A27,B75	A32,B75
A27,B76	A32,B76	A27,B77	A32,B77
A28,B77	A31,B77	A28,B78	A31,B78
A28,B79	A31,B79	A28,B80	A31,B80
A29,B80	A30,B80	A29,B81	A30,B81
A29,B81	A31,B81	A27,B81	A32,B81
A27,B82	A32,B82	A26,B82	A33,B82
A25,B82	A34,B82		
A5, B82	A54,B82	A4,B82	A55,B82
A3,B82	A56,B82	A2,B81	A57,B81
A1,B81	A58,B81	A1,B80	A58,B80
A2,B80	A57,B80	A2,B79	A57,B79
A2,B78	A57,B78	A2,B77	A57,B77
A3,B77	A56,B77	A3, B76	A56,B76
A3,B75	A56,B75	A3,B74	A56,B74
A4,B74	A55,B74	A4,B73	A55,B73
A4,B72	A55,B72	A4,B71	A55,B71
A5,B71	A54,B71	A5,B70	A54,B70
A5,B69	A54,B69	A4,B69	A55,B69
A3,B69	A56,B69	A3,B68	A56,B68

Contd..

A2,B68	A57,B63	A1,B68	A58,B68
A1,B67	A58,B67	A2,B67	A57,B67
A2,B66	A57,B66	A8,B65	A57,B65
A3,B65	A56,B65	A3,B64	A56,B64
A3,B63	A56,B63	A4,B63	A55,B63
A4,B62	A55,B62	A4,B61	A55,B61
A4,B60	A55,B60	A4,B59	A55,B59
A3,B59	A56,B59	A2,B58	A57,B59
A2,B58	A57,B58	A1,B58	A58,B58
A1,B57	A58,B57	A2,B57	A57,B57
A2,B56	A57,B56	A3,B55	A56,B56
A4,B55	A57,B55	A41,B54	A57,B54
A5,B54	A58,B54	A5,B53	A58,B53
A5,B52	A58,B52	A4,B52	A57,B52
A4,B51	A57,B51	A3,B51	A56,B51
A3,B50	A56,B50	A2,B50	A57,B50
A2,B49	A57,B49	A2,B48	A57,B48
A1,B48	A58,B48	A1,B47	A48,B47
A2,B47	A57,B47	A2,B46	A57,B46
A3,B46	A56,B46	A41,B46	A55,B46
A5,B46	A54,B46	A5,B45	A54,B45
A5,B44	A54,B44	A4,B44	A55,B44
A4,B43	A55,B43	A4,B42	A55,B42
A4,B41	A55,B41	A4,B40	A55,B40

Contd..

A5,B40	A54,B40	A5,B39	A54,B39
A5,B38	A54,B38	A4,B38	A55,B38
A3,B38	A56,B38	A2,B38	A57,B38
A2,B37	A57,B37	A1,B37	A58,B37
A1,B36	A58,B36	A2,B36	A57,B36
A2,B35	A57,B35	A2,B34	A57,B34
A3,B34	A56,B34	A3,B33	A56,B33
A4,B33	A55,B33	A4,B32	A55,B32
A5,B32	A54,B32	A5,B31	A54,B31
A5,B30	A54,B30	A4,B30	A55,B30
A4,B29	A55,B29	A3,B29	A56,B29
A3,B28	A56,B28	A2,B28	A57,B28
A2,B27	A57,B27	A1,B27	A58,B27
A1,B26	A58,B26	A2,B26	A57,B26
A2,B25	A57,B25	A3,B25	A56,B25
A4,B25	A55,B25	A4,B24	A55,B24
A4,B23	A55,B23	A4,B22	A56,B22
A4,B21	A55,B21	A3,B21	A56,B21
A3,B20	A56,B20	A3,B19	A56,B19
A2,B19	A57,B19	A2,B18	A57,B18
A2,B17	A57,B17	A1,B17	A58,B17
A1,B16	A58,B16	A2,B16	A57,B16
A3,B16	A56,B16	A3,B15	A56,B15
A4,B15	A55,B15	A5,B15	A54,B15

Contd..

A5,B14	A54,B14	A5,B13	A54,B13
A4,B13	A55,B13	A4,B12	A55,B12
A4,B11	A55,B11	A4,B10	A55,B10
A3,B10	A56,B10	A3,B9	A56,B9
A3,B8	A56,B38	A3,B7	A56,B7
A2,B7	A57,B7	A2,B6	A57,B6
A2,B5	A57,B5	A2,B4	A57,B4
A1,B4	A58,B4	A1,B3	A58,B3
A2,B3	A57,B3	A3,B37	A56,B3
A3,B3	A56,B2	A4,B2	A55,B2
A5,B2	A54,B2	A6,B2	A53,B2
A7,B2	A52,B2		

APPENDIX-B

VALUES OF CAPACITORS

(The nodal arrangement is given in plate XIII)

A-MAIN AREA OF STUDY

1		2	
Nodes	Capacitance in PF	Nodes	Capacitance in Pl
A1,B3	2000	A1,B4	1000
A1,B1	4000	A1,B17	1000
A1,B26 to A1,B27	4000	A1,B36	1000
A1,B37	4000	A1,B47	3000
A1,B48	1100	A1,B58	3000
A1,B59	3000	A1,B67	1100
A1,B68	3000	A1,B80	1000
A1,B81	3000		
A2,B3	4000	A2,B4	4000
A2,B5	4000	A2,B6	4000
A2,B37	1000	A2,B16	4000
A2,B17	4000	A2,B18	4000
A2,B19	560	A2,B25	2000
A2,B26	4000	A2,B27	4000
A2,B28	4000	A2,B34	560
A2,B35 to A2,B37	4000	A2,B38	560
A2,B46	475	A2,B47 toA2,B49	3000
A2,B50	475	A2,B56 toA2,B58	3000

Contd..2

A2,B59	2000	A2,B65	475
A2,B66 to A2,B68	3000		
A3,B2	560	A3,B3 to A3,B9	4000
A3,B10	1000	A3,B15	2000
A3,B16 toA3,B20	4000	A3,B21	560
A3,B26 to A3,B27	4000	A3,B33 to A3,B38	4000
A3,B46	2000	A3,B47 to A3,B51	3000
A3,B55 to A3,59	3000	A3,B63	475
A3,B64 to A3,B68	3000	A3,B6	2000
A3,B74	1100	A3,B75 to Ae,B81	3000
A4,B2	1000	A4,B3 to A4,B11	4000
A4,B12	2000	A4,B13	1000
A4,B15 to Ar,B22	4000	A4,B23	560
A4,B24 to A4,B30	4000	A4,B32 to A4,B38	4000
A4,B40	560	A4,B41	1100
A4,B42	2000	A4,B43	1100
A4,B44	475	A4,B46 to A4,B52	3000
A4,B54 to Ar,B60	3000	A4,B61	475
A4,B62 to ar,B69	3000	A4,B71	475
A4,B72 to A4,B81	3000	A4,B82	1100
A5,B2 to A5,B33	4000	A5,B35 toA5,B82	3000
A6,B2 to A6,B33	4000	A6,B34toA6,B82	3000
A7,B1	1000	A7,B2 to A7,B33	4000
A7,B34 to A7,B58	3000	A7,B59 to A7,B68	4000

Contd..

A7,B69 to A7,B82	3000	A7,B83	475
A8,B1	2000	A8,B2 to A8,B33	4000
A8,B34 to A8,B36	3000	A8,B37 to A8,B57	2000
A8,B58	3000	A8,B59 to A8,B68	4000
A8,B69 to A8,B82	3000	A8,B83	1000
A9,B1	3000	A9,B2 to A9,B33	4000
A9,B34 to A9,B38	3000	A9,B39 to A9,B50	2000
A9,B51 to A9,B57	3000	A9,B58 to A9,B68	4000
A9,B69 to A9,B82	3000	A9,B83	2000
A10,B1	5000	A10,B2 to A10,B35	4000
A10,B36 to A10,B41	3000	A10,B42 to A10,B47	2000
A10,B48 to A10,B57	3000	A10,B58 to A10,B68	3000
A10,B69 to A10,B82	3000	A10,B83	3000
A11÷B1 to A11,B36	5000	A11,B37,A11,B39	4000
A11,B40, to A11,B49	3000	A11,B50 to A11,B68	4000
A11,B69 to A11,B83	3000		
A12,B1	5000	A12,B2 to A12,B17	6000
A12,B18 to A12,B20	5000	A12,B21 to A12,B25	7000
A12,B26 to A12,B37	6000	A12,B38 to A12,B40	5000
A12,B41 to A12,B43	4000	A12,B44 to A12,B53	3000
A12,B54 to A12,B73	4000	A12,B74 to A12,B82	3000
A12,B83	3000		
A13,B1	5000	A13,B2 to A13,B31	8000

Contd..

A13,B32 to A13,B36	7000	A13,B37 to A13,B38	6000
A13,B39 to A13,B47	5000	A13,B48 to A13,B50	4000
A13,B57 to A13,B58	5000	A13,B59 to A13,B62	4000
A13,B63 to A13,B67	5000	A13,B68	4000
A13,B69 to A13,B82	3000	A13,B83	3000
A14,B1	5000	A14,B2 to A14,B29	10,000
A14,B30 to A14,B36	8000	A14,B37 to A14,B38	7000
A14,B39 to A14,B40	6000	A14,B41 to A14,B58	5000
A14,B59 to A14,B63	4000	A14,B64 to A14,B67	5000
A14,B68	4000	A14,B69 to A14,B82	3000
A14,B83	3000		
A14,B1	6000	A15,B2 to A15,B25	12000
A15,B25 to A15,B33	10,000	A15,B34 to A15,B36	8000
A15,B37 to A15,B38	7000	A15,B39 toA15,B40	6000
A15,B41 to A15,B49	5000	A15,B50 to A15,B59	6000
A15,B60 to A15,B66	5000	A15,B67 to A15,B68	4000
A15,B69 to A15,B82	3000	A15,B83	6000
A16,B1	7000	A16,B2 to A16,B13	13000
A16,B14 toA16,B16	14000	A16,B17 to A16,B23	13000
A16,B24 to A16,B25	12000	A16,B26 to A16,B27	13000
A16,B28 to A16,B30	12000	A16,B31 to A16,B33	11000
A16,B34 to A16,B38	10,000	A16,B39 to A16,B40	80,000
A16,B41 to A16,B44	7000	A16,B45 to A16,B60	6000

Contd..

A16,B61 to A16,B70	5000	A16,B71 to A16,B82	3000
A16,B83	8000		
A17,B1	7000	A17,B2 to A17,B23	14000
A17,B24 to A17,B29	12000	A17,B30 to A17,B33	10,000
A17,B34 to A17,B38	8000	A17,B39 to A17,B58	7000
A17,B59 to A17,B61	6000	A17,B62 to A17,B64	5000
A17,B65 to A17,B68	4000	A17,B69 to A17,B82	3000
A17,B83	8000		
A18,B1	7000	A18,B2 to A18,B21	16,000
A18,B22 to A18,B26	15000	A18,B27 to A18,B25	8000
A18,B39 to A18,B58	7000	A18,B59 to A18,B62	6000
A18,B63 to A18,B66	5000	A18,B67 to A18,B82	4000
A18,B83	8000		
A19,B1	7000	A19,B2 to A19,B23	20,000
A19,B24	18000	A19,B25 to A19,B26	16,000
A19,B27 to A19,B28	15000	A19,B29 to A19,B30	12,000
A19,B31 to A19,B32	10,000	A19,B33	8,000
A19,B34 to A19,B38	7000	A19,B39 to A19,B63	6000
A19,B64 to A19,B82	5000	A19,B83	8000
A20,B1	7000	A20,B2 to A20,B21	15000
A20,B22 to A20,B23	14000	A20,B24,to A20,B28	12000
A20,B29 to A20,B33	8000	A20,B34 to A20,B82	6000
A20,B83	8000	[illegible]	

Contd..

A21,B1	5000	A21,B2 to A21,B24	12,000
A21,B25 to A21,B26	10000	A21,B27 to A21,B29	80000
A21,B30 to A21,B31	6000	A21,B32 to A21,B33	7000
A21,B34 to A21,B39	5000	A21,B4o to A21,B52	6000
A21,B53 to A21,B82	7000	A21,B83	5100Ø
A22,B1	2200	A22,B2 to A22,B24	10,000
A22,B25 to A22,B27	8000	A22,B28 to A22,B31	6000
A22,B32 to A22,B44	5000	A22,B45 to A22,B50	6000
A22,B51 to A22,B64	7000	A22,B65 to A22,B82	8000
A22,B83	3000		
A23,B1	1000	A23,B2 to A23,B27	8000
A23,B28 to A23,B45	5000	A23,B46 to A23,B64	7000
A23,B65 to A23,B74	8000	A23,B77 to A23,B82	10,000
A23,B83	1000		
A24,B2 to A24,B20	7000	A24,B21 to A24,B26	8000
A24,B27 to A24,B42	5000	A24,B43 to A24,B60	7000
A24,B61 to A24,B68	8000	A24,B69 to A24,B82	10000
A24,B2 to A24,B20	7000	A24,B21 to A25,B26	5000
A25,B27 to A25,B42	5000	A25,B43 toA25,B60	7000
A25,B61 to A25,B64	8000	A25,B65 to A25, B82	10000

Contd..

A26,B2	2200	A26,B3 to A26,B12	7000
A26,B13	1100	A26,B15 to A26,B22	7000
A26,B23	1100	A26,B24	7000
A26,B25 to A26,B30	7000	A26,B32 to A26,B38	7000
A26,B40	1100	A26,B41	2200
A26,B42	4000	A26,B43	3000
A26,B44	1300	A26,B61	10000
A26,B54 to A26,B60	10000	A26,B61	1300
A26,B62 to A26,B69	10000	A26,B71	1000
A26,B72 to A26,B81	10000	A26,B82	3000
A27,B2	1100	A27,B3 to A27,B9	2200
A27,B15	4700	A27,B16 to A27,B20	7000
A27,B21	1100	A27,B25 to A27,B29	7000
A27,B33 to A27,B37	7000	A27,B38	4100
A27,B46	5000	A27,B47 to A27,B51	10,000
A27,B55 to A27,B59	10000	A27,B63	1300
A27,B64 to A27,B68	10000	A27,B69	5000
A27,B74	3000	A27,B75 to A27,B81	10,000
A27,B82	1000		
A28,B3 to A28,B6	7000	A28,B7	2200
A28,B16 to A28,B18	7000	A28,B19	1100
A28,B25	4700	A28,B26 to A28,B28	7000
A28,B34	1100	A28,B35,to A28,B37	7000

Contd..

A28,B38	1100	A28,B46	1300
A28,B47 to A28,B49	10000	A28,B59	5000
A28,B65	1000	A28,B66 to A28,B68	10000
A28,B77	3000	A28,B78 to A28,B81	10000
A29,B3	47000	A29,B4	2200
A29,B16	7000	A29,B17	2200
A29,B25 to A29,B26	7000	A29,B47	10,000
A29,B48	3000	A29,B57 to A29,B58	10,000
A29,B67	3300	A29,B68	10,000
A29,B81	3000	A29,B82	5,000

B- CONFORMABLY MAPPED AREA

A32,B4	8000	A32,B5	9,000
A32,B6	10,000	A32,B17	9,000
A32,B18	11,000	A32,B26	8,000
A32,B27	10,000	A32,B35	13,000
A32,B36	15,000	A32,B37	17,000
A32,B47	17,000	A32,B48	15,000
A32,B49	13,000	A32,B57	12,000
A32,B58	10,000	A32,B66	15,000
A32,B67	13,000	A32,B78	11,000
A32,B79	13,000	A32,B80	12,000

Contd..

A33, B3	8,000	A33,B4	8,000
A33,B5	9,000	A33,B6	11,000
A33,B7	11,000	A33,B8	13,000
A33,B9	14,000	A33,B16	8,000
A33,B17	10,000	A33,B18	11,000
A33,B19	13,000	A33,B20	15,000
A33,B26	9,000	A33,B27	11,000
A33,B28	13,000	A33,B34	10,000
A33,B35	12,000	A33,B36	13,000
A33,B37	16,000	A33,B47	23,000
A33,B48	19,000	A33,B49	17,000
A33,B50	14,000	A33,B56	19,000
A33,B57	16,000	A33,B58	13,000
A33,B64	21,000	A33,B65	18,000
A33,B66	16,000	A33,B67	14,000
A33,B68	12,000	A33,B75	20,000
A33,B76	18,000	A33,B77	16,000
A33,B78	15,000	A33,B79	13,000
A33,B80	12,000	A33,B81	11,000
A34,B3	8,000	A34,B4	8,000
A34,B5	10,000	A34,B6	11,000
A34,B7	12,000	A34,B8	13,000
A34,B9	14,000	A34,B10	16,000
A34,B11	18,000	A34,B12	20,000

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A34,B15	11,000	A34,B16	12,000
A34,B17	13,000	A34,B18	16,000
A34,B19	18,000	A34,B20	22,000
A34,B21	25,000	A34,B22	22,000
A34,B23	25,000	A34,B24	7,000
A34,B25	9,000	A34,B26	11,000
A34,B27	13,000	A34,B28	15,000
A34,B29	18,000	A34,B33	11,000
A34,B34	13,000	A34,B35	15,000
A34,B36	18,000	A34,B37	22,000
A34,B41	8,000	A34,B42	9,000
A34,B43	13,000	A34,B44	12,000
A34,B47	35,000	A34,B48	30,000
A34,B49	25,000	A34,B50	20,000
A34,B51	17,000	A34,B55	30,000
A34,B56	24,000	A34,B57	20,000
A34,B58	17,000	A34,B59	15,000
A34,B60	11,000	A34,B61	41,000
A34,B62	35,000	A34,B63	30,000
A34,B64	26,000	A34,B65	22,000
A34,B66	19,000	A34,B67	17,000
A34,B68	15,000	A34,B72	33,000
A34,B73	30,000	A34,B74	26,000
A34,B75	23,000	A34,B76	21,000
A34,B77	19,000	A 34,B78	17,000

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A34,B79	16,000	A34,B80	14,000
A34,B81	12,000		
A35,B3	9,000	A35,B4	10,000
A35,B5	11,000	A35,B8	12,000
A35,B9	13,000	A35,B10	15,000
A35,B18	13,000	A35,B19	15,000
A35,B20	17,000	A35,B21	20,000
A35,B22	23,000	A35,B23	27,000
A35,B24	33,000	A35,B25	39,000
A35,B26	12,000	A35,B27	14,000
A35,B28	18,000	A35, B29	20,000
A35,B30	26,000	A35,B31	31,000
A35,B32	42,000	A35,B33	13,000
A32,B34	16,000	A35,B35	27,000
A35,B36	25,000	A35,B37	30,000
A35,B38	36,000	A35,B39	11,000
A35,B40	12,000	A35,B41	21,000
A35,B42	22,000	A35,B43	21,000
A35,B44	19,000	A35,B45	18,000
A35,B46	58,000	A35,B47	49,000
A35,B48	40,000	A35,B49	43,000
A35,B50	26,000	A35,B51	20,000
A35,B52	68,000	A35,B53	53,000
A35,B54	42,000	A35,B55	32,000
A35,B56	28,000	A35,B57	23,000

Contd..

A35,B58	19,000	A35,B59	64,000
A35,B60	53,000	A35,B61	44,000
A35,B62	37,000	A35,B63	34,000
A35,B64	27,000	A35,B65	24,000
A35,B66	20,000	A35,B67	67,000
A35,B68	57,000	A35,B69	51,000
A35,B70	44,000	A35,B71	40,000
A35,B72	34,000	A35,B73	31,000
A35,B74	27,000	A35,B75	24,000
A35,B76	21,000	A35,B77	19,000
A35,B78	17,000		
A36,B3	10,000	A36,B4	10,000
A36,B5	11,000	A36,B6	13,000
A36,B7	14,000	A36,B8	16,000
A36,B22	18,000	A36,B23	21,000
A36,B24	25,000	A36,B25	30,000
A36,B26	36,000	A36,B27	53,000
A36,B28	64,000	A36,B29	20,000
A36,B30	24,000	A36,B31	30,000
A36,B32	39,000	A36,B33	48,000
A36,B34	20,000	A36,B35	27,000
A36,B36	34,000	A36,B37	42,000
A36,B38	54,000	A36,B39	63,000
A36,B40	19,000	A36,B41	21,000
A36,B42	22,000	A36,B43	34,000
A36,B44	31,000	A36,B45	192,000
A36,B46	85,000	A36,B47	68,000

Contd.

A36,B48	55,000	A36,B49	43,000
A36,B50	33,000	A36,B51	91,000
A36,B52	77,000	A36,B53	62,000
A36,B54	49,000	A36,B55	39,000
A36,B56	32,000	A36,B57	106,000
A36,B58	85,000	A36,B59	70,000
A36,B60	58,000	A36,B61	49,000
A36,B62	41,000	A36,B63	34,000
A36,B64	28,000	A36,B65	95,000
A36,B66	80,000	A36,B67	70,000
A36,B68	61,000	A36,B69	53,000
A36,B70	47,000	A36,B71	41,000
A36,B72	36,000	A36,B73	32,000
A36,B74	28,000		
A37,B3	10,000	A37,B4	10,000
A37,B5	12,000	A37,B6	13,000
A37,B7	14,000	A37,B23	32,000
A37,B24	39,000	A37,B25	47,000
A37,B26	58,000	A37,B27	71,000
A37,B28	90,000	A37,B29	111,000
A37,B30	36,000	A37,B31	45,000
A37,B32	59,000	A37,B33	77,000
A37,B34	98,000	A37,B35	35,000
A37,B36	46,000	A37,B37	62,000
A37,B38	79,000	A37,B39	1000,000

Contd..

A37,B40	32,000	A37,B41	36,000
A37,B42	60,000	A37,B43	58,000
A37,B44	41,000	A37,B45	162,000
A37,B46	128,000	A37,B47	100,000
A37,B48	75,000	A37,B49	57,000
A37,B50	159,000	A37,B51	125,000
A37,B52	91,000	A37,B53	73,000
A37,B54	58,000	A37,B55	179,000
A37,B56	145,000	A37,B57	116,000
A37,B58	94,000	A37,B59	76,000
A37,B60	62,000	A37,B61	52,000
A37,B62	166,000	A37,B63	139,000
A37,B64	117,000	A37,B65	100,000
A37,B66	85,000	A37,B67	73,000
A37,B68	63,000	A37,B69	56,000
A38,B3	10,000	A38,B4	10,000
A38,B5	12,000	A38,B6	14,000
A38,B7	14,000	A38,B26	63,000
A38,B27	79,000	A38,B28	101,000
A38,B29	128,000	A38,B30	161,000
A38,B31	231,000	A38,B32	79,000
A38,B33	91,000	A38,B34	126,000
A38,B35	182,000	A38,B36	65,000
A38,B37	90,000	A38,B38	124,000

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A38,B39	166,000	A38,B40	55,000
A38,B41	64,000	A38,B42	110,000
A38,B43	105,000	A38,B44	90,000
A38,B45	269,000	A38,B46	201,000
A38,B47	147,000	A38,B48	106,000
A38,B49,	295,000	A38,B50	204,000
A38,B51	148,000	A38,B52	128,000
A38,B53	375,000	A38,B54	261,000
A38,B55	208,000	A38,B56	164,000
A38,B57	128,000	A38,B58	102,000
A38,B59	316,000	A38,B60	258,000
A38,B61	211,000	A38,B62	176,000
A38,B63	124,000	A38,B64	104,000
A38,B65	88,000		
A39,B2	9,000	A39,B3	10,000
A39,B4	11,000	A39,B5	12,000
A39,B6	14,000	A39,B7	14,000
A39,B29	150,000	A39,B30	189,000
A39,B31	252,000	A39,B32	343,000
A39,B33	117,000	A39,B34	165,000
A39,B35	238,000	A39,B36	352,000
A39,B37	134,000	A39,B38	200,000
A39,B39	290,000	A39,B40	400,000
A39,B41	133,000	A39,B42	229,000
A39,B43	216,000	A39,B44	648,000

Contd.

A39,B45	471,000	A39,B46	324,000
A39,B47	218,000	A39,B48	477,000
A39,B49	386,000	A39,B50	267,000
A39,B51	190,000	A39,B52	557,000
A39,B53	409,000	A39,B54	307,000
A39,B55	244,000	A39,B56	684,000
A39,B57	536,000	A39,B58	420,000
A39,B59	338,000	A39,B60	273,000
A39,B61	224,000		
A40,B2	9,000	A40,B3	10,000
A40,B4	10,000	A40,B5	12,000
A40,B6	14,000	A40,B7	14,000
A40,B32	406,000	A40,B33	588,000
A40,B34	854,000	A40,B35	294,000
A40,B36	483,000	A40,B37	780,000
A40,B38	328,000	A40,B39	540,000
A40,B40	840,000	A40,B41	308,000
A40,B42	343,000	A40,B43	500,000
A40,B44	13,63,000	A40,B45	875,000
A40,B46	533,000	A40,B47	726,000
A40,B48	748,000	A40,B49	477,000
A40,B50	13,86,000	A40,B51	954,000
A40,B52	659,000	A40,B53	1,790,000
A40,B54	13,00,000	A40,B55	965,000
A40,B56	740,000	A40,B57	576,000

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A41,B2	9,000	A41,B3	10,000
A41,B4	11,000	A41,B5	12,000
A41,B6	14,000	A41,B7	14,000
A41,B35	1620,000	A41,B36	2580,000
A41,B37	1133,000	A41,B38	1607,000
A41,B39	1036,000	A41,B40	1984,000
A41,B41	880,000	A41,B42	1772,000
A41,B43	1431,000	A41,B44	322,000
A41,B45	1681,000	A41,B46	2607,000
A41,B47	18,39,000	A41,B48	4,20,00,000
A41,B49	2,62,00,000	A41,B50	
A41,B51	41,00,000	A41,B52	2,80,00,000
A41,B53	19,70,000		
A42,B2	9,000	A42,B3	10,000
A42,B4	11,000	A42,B5	13,000
A42,B6	14,000	A42,B37	6500,000
A42,B38	13700,000	A42,B9	7756,000
A42,B40	5250,000	A42,B41	8433,000
A42,B42	8850,000	A42,B43	21600,000
A42,B44	8500,000	A42,B45	1255,000
A42,B46	22150,000	A42,B47	2787,000
A42,B48	20800,000	A42,B49	11800,000

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A43,B2	9,000	A43,B3	10,000
A43,B4	11,000	A43,B5	13,000
A53,B6	14,000	A43,B40	214,000,000
A43,B41	327500,000	A43,B42	143,000,000
A43,B43	535000,000	A43,B44	348,000,000
A43,B45	334,000,000	A43,B46	
A44,B2	9,000	A44,B3	10,000
A44,B4	11,000	A44,B5	12,000
A44,B6	14,000		
A45,B2	9,000	A45,B3	10,000
A45,B4	11,000	A45,B5	13,000
A45,B6	14,000	A45,B40	109500,000
A45,B41	171500,000	A45,B42	37975,000
A45,B43	140388,000	A45,B44	92000,000
A45,B45	88000,000		
A46,B2	9,000	A46,B3	10,000
A46,B4	11,000	A46,B5	13,000
A46,B6	14,000	A46,B37	3310,000
A46,B38	7200,000	A46,B39	4080,000
A46,B40	2740,000	A46,B41	702,000
A46,B42	2367,000	A46,B43	5757,000
A46,B44	2250,000	A46,B45	3324,000
A46,B46	5859,000	A46,B47	2787,000
A46,B48,	5500,000	A46,B49	3140,000

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A47,B2	9,000	A47,B3	10,000
A47,B4	11,000	A47,B5	12,000
A47,B6	14,000	A47,B35	8,50,000
A47,B36	13,30,000	A47,B37	5,90,000
A47,B38	8,34,000	A47,B39	5,38,000
A47,B40	10,40,000	A47,B41	4,58,000
A47,B42	4,73,000	A47,B43	3,82,000
A47,B44	75,20,000	A47,B45	3,48,000
A47,B46	6,95,000	A47,B47	4,91,000
A47,B48	10,97,000	A47,B49	6,96,000
A47,B50	1,76,000	A47,B51	10,70,000
A47,B52	7,40,000	A47,B53	5,20,000
A48,B2	9,000	A48,B3	10,000
A48,B4	11,000	A48,B5	12,000
A48,B6	14,000	A48,B32	2,11,000
A48,B33	3,05,000	A48,B34	4,44,000
A48,B35	1,53,000	A48,B36	2,51,000
A48,B37	4,05,000	A48,B38	1,71,000
A48,B39	2,80,000	A48,B40	4,36,000
A48,B41	1,60,000	A48,B42	1,78,000
A48,B43	1,33,000	A48,B44	3,64,000
A48,B45	2,33,000	A48,B46	1,42,000
A48,B47	3,37,000	A48,B48	2,09,000
A48,B49	1,27,000	A48,B50	3,70,000

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A48,B51	2,55,000	A48,B52	1,76,000
A48,B53	4,68,000	A48,B54	3,45,000
A48,B55	2,55,000	A48,B56	1,95,000
A48,B57	1,52,000		
A49,B2	9,000	A49,B3	10,000
A49pB4	11,000	A49,B5	12,000
A49,B6	x 14,000	A49,B7	14,000
A49,B29	28,000	A49,B30	98,000
A49,B31	1,31,000	A49,B32	1,78,000
A49,B33	61,000	A49,B34	85,000
A49,B35	1,24,000	A49,B36	1,83,000
A49,B37	70,000	A49,B38	1,04,000
A49,B39	1,51,000	A49,B40	2,07,000
A49,B41	70,000	A49,B42	61,000
A49,B43	58,000	A49,B44	1,73,000
A49,B45	1,26,000	A49,B46	86,000
A49;B47	58,000	A49pB48	1,27,000
A49,B49	1,03,000	A49,B50	71,000
A49,B51	51,000	A49,B52	1,48,000
A49,B53	1,09,000	A49,B54	82,000
A49,B55	65,000	A49,B56	1,80,000
A49,B57	1,42,000	A49,B58	1,11,000
A49,B59	88,000	A49,B60	73,000
A49,B61	60,000		

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A50,B2	9,000	A50,B3	10,000
A50,B4	10,000	A50,B5	12,000
A50,B6	13,000	A50,B7	14,000
A50,B26	33,000	A50,B27	41,000
A50,B28	52,000	A50,B29	66,000
A50,B30	84,000	A50,B31	1,20,000
A50,B32	41,000	A50,B33	57,000
A50,B34	65,000	A50,B35	95,000
A50,B36	34,000	A50,B37	47,000
A50,B38	64,000	A50,B39	86,000
A50,B40	29,000	A50,B41	33,000
A50,B42	29,000	A50,B43	28,000
A50,B44	24,000	A50,B45	72,000
A50,B46	54,000	A50,B47	39,000
A50,B48	28,000	A50,B49	79,000
A50,B50	55,000	A50,B51	40,000
A50,B52	34,000	A50,B53	1,00,000
A50,B54	70,000	A50,B55	50,000
A50,B56	44,000	A50,B57	34,000
A50,B58	27,000	A50,B59	84,000
A50,B60	69,000	A50,B61	56,000
A50,B62	47,000	A50,B63	33,000
A50,B64	28,000	A50,B65	24,000

Contd..

A51,B2	9,000	A51,B3	10,000
A51,B4	10,000	A51,B5	12,000
A51,B6	13,000	A51,B7	14,000
A51,B23	17,000	A51,B24	20,000
A51,B25	24,000	A51,B26	30,000
A51,B27	37,000	A51,B28	46,000
A51,B29	57,000	A51,B30	19,000
A51,B31	23,000	A51,B32	29,000
A51,B33	40,000	A51,B34	51,000
A51,B35	18,000	A51,B36	24,000
A51,B37	32,000	A51,B38	41,000
A51,B39	52,000	A51,B40	16,000
A51,B41	19,000	A51,B42	16,000
A51,B43	15,000	A51,B44	14,000
A51,B45	43,000	A51,B46	34,000
A51,B47	27,000	A51,B48	20,000
A51,B49	15,000	A51,B50	42,000
A51,B51	33,000	A51,B52	24,000
A51,B53	19,000	A51,B54	15,000
A51,B55	48,000	A51,B56	39,000
A51,B57	31,000	A51,B58	25,000
A51,B59	20,000	A51,B60	17,000
A51,B61	14,000	A51,B62	44,000
A51,B63	37,000	A51,B64	31,000

Contd.

A51,B65	27,000	A51,B66	23,000
A51,B67	20,000	A51,B68	17,000
A51,B69	15,000		
A52,B2	9,000	A52,B3	10,000
A52,B4	10,000	A52,B5	11,000
A52,B6	13,000	A52,B7	14,000
A52,B21	11,000	A52,B22	9,000
A52,B23	11,000	A52,B24	13,000
A52,B25	16,000	A52,B26	18,000
A52,B27	27,000	A52,B28	33,000
A52,B29	10,000	A52,B30	12,000
A52,B31	16,000	A52,B32	20,000
A52,B33	25,000	A52,B34	1,10,000
A52,B35	14,000	A52,B36	17,000
A52,B37	22,000	A52,B38	27,000
A52,B39	33,000	A52,B40	10,000
A52,B41	11,000	A52,B42	11,000
A52,B43	10,000	A52,B44	8,000
A52,B45	27,000	A52,B46	23,000
A52,B47	18,000	A52,B48	15,000
A52,B49	11,000	A52,B50	9,000
A52,B51	24,000	A52,B52	21,000
A52,B53	21,000	A52,B54	17,000
A52,B55	13,000	A52,B56	10,000
A52,B57	8,000	A52,B58	28,000

Contd..

A52,B59	23,000	A52,B60	15,000
A52,B61	13,000	A52,B62	10,000
A52,B63	9,000	A52,B64	8,000
A52,B65	25,000	A52,B66	22,000
A52,B67	19,000	A52,B70	12,000
A52,B71	11,000	A52,B72	10,000
A52,B73	8,000	A52,B74	8,000
A53,B3	9,000	A53,B4	10,000
A53,B5	11,000	A53,B6	14,000
A53,B7	15,000	A53,B18	6,000
A53,B19	8,000	A53,B20	9,000
A53,B21	10,000	A53,B22	12,000
A53,B23	14,000	A53,B24	14,000
A53,B25	20,000	A53,B26	6,000
A53,B27,	4,000	A53,B28	9,000
A53,B29	10,000	A53,B30	13,000
A53,B31	17,000	A53,B32	22,000
A53,B33	6,000	A53,B34	8,000
A53,B35	14,000	A53,B36	13,000
A53,B37	16,000	A53,B38	19,000
A53,B39	6,000	A53,B40	6,000
A53,B41	11,000	A53,B42	6,000
A53,B43	6,000	A53,B44	5,000
A53,B45	5,000	A53,B46	15,000

Contd.

A53,B47	13,000	A53,B48	11,000
A53,B49	11,000	A53,B50	7,000
A53,B51	5,000	A53,B52	18,000
A53,B53	14,000	A53,B54	11,000
A53,B55	8,000	A53,B56	8,000
A53,B57	6,000	A53,B58	5,000
A53,B59	17,000	A53,B60,	14,000
A53,B61	12,000	A53,B62	10,000
A53,B63	9,000	A53,B64	7,000
A53,B65	~~1~~6,000	A53,B66	5,000
A53,B67	18,000	A53,B68	15,000
A53,B69	14,000	A53,B70	12,000
A53,B71	11,000	A53,B72	9,000
A53,B73	8,000	A53,B74	7,000
A53,B75	6,000	A53,B76	6,000
A53,B77	5,000	A53,B78	5,000
A54,B3	4,000	A54,B4	4,000
A54,B5	5,000	A54,B6	5,000
A54,B7	6,000	A54,B8	7,000
A54, B9	7,000	A54,B10	8,000
A54, B11	9,000	A54,B12	11,000
A54,B16	5,000	A54,B17	5,000
A54,B18	6,000	A54,B19.	7,000

Contd..

A54,B20,	8,000	A54,B21	9,000
A54,B22	11,000	A54,B23	12,000
A54,B24	4,000	A54,B25	5,000
A54,B26	5,000	A54,B27	7,000
A54,B28	8,000	A54,B29	9,000
A54,B30	11,000	A54,B33	5,000
A54,B34	6,000	A54,B35	8,000
A54,B36	9,000	A54,B37	11,000
A54,B41	4,000	A54,B42	5 ,000
A54,B43	4,000	A54,B47	9,000
A54,B48	8,000	A54,B49	7,000
A54,B50	5,000	A54,B51	5,000
A54,B55	8,000	A54,B56	6,000
A54,B57	6,000	A54,B58	5,000
A54,B59	4,000	A54,B60	3,000
A54,B61	12,000	A54,B62	9,000
A54,B63	8,000	A54,B64	7,000
A54,B65	6,000	A54,B66	5,000
A54,B67	5,000	A54,B68	4,000
A54,B72	8,000	A54,B73	8,000
A54,B74	7,000	A54,B75	6,000
A54,B76	6,000	A54,B77	5, 000
A54,B78	5,000	A54,B79	5, 000

Contd.

A54,B80	4,000	A54,B81	3,000
A55,B3	4,000	A55,B34	5,000
A55,B5	5,000	A55,B6	6,000
A55,B7	7,000	A55,B8	7,000
A55,B9	8,000	A55,B16	5,000
A55,B17	6,000	A55,B18	6,000
A55,B19	7,000	A55,B20	8,000
A55,B26	5,000	A55,B27	6,000
A55,B28	7,000	A55,B29	9,000
A55,B34	6,000	A55,B35	7,000
A55,B36	7,000	A55,B37	10,000
A55,B47	7,000	A55,B48	6,000
A55,B49	5,000	A55,B50	4,000
A55,B56	6,000	A55,B57	5,000
A55,B58	4,000	A55,B64	6,000
A55,B65	5,000	A55,B66	5,000
A55,B67	4,000	A55,B68	4,000
A55,B75	6,000	A55,B76	5,000
A55,B77	5,000	A55,B78	5,000
A55,B79	4,000	A55,B80	4,000
A55,B81	3,000		

Contd..

A56,B4	5,000	A56,B5	5,000
A56,B6	6,000	A56,B17	5,000
A56,B18	6,000	A56,B26	6,000
A56,B27	6,000	A56,B35	5,000
A56,B36	6,000	A56,B37	7,000
A56,B47	5,000	A56,B48	5,000
A56,B49	4,000	A56,B57	4,000
A56,B58	4,000	A56,B66	5,000
A56,B67	4,000	A56,B78	4,000
A56,B79	4,000	A56,B80	4,000