MODELLING GROUNDWATER TABLE FLUCTUATION IN THE INLAND VALLEY OF GIDAN-KWANO NIGER STATE, NIGERIA.

BY

ADEYANJU, EZEKIEL AMOLE
(M. ENG. / SEET / 1999 /377).

A PROJECT REPORT SUBMITTED TO
AGRICULTURAL ENGINEERING DEPARTMENT,
FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA.

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR
THE AWARD OF MASTERS DEGREE (M. ENG.) IN
AGRICULTURAL ENGINEERING (SOIL AND WATER
OPTION)

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CERTIFICATION

Ezekiel A. Adeyanju, a masters student in the Department of Agricultural Engineering with registration number: M. ENG./1999/377, has satisfactorily completed the requirement for the project works for the award of masters degree in Agricultural Engineering. The work embarked upon in the project area is original, I certify that it was carried out under my supervision.

Dr. N. A. Egharevba

Project Supervisor

Date

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Thanks be to God Almighty who gave me the courage, Knowledge and guidance on my academic for successful completion of masters degree programme. I would like to express my gratitude to my project supervisor, Dr. N. A. Egharevba, whose criticisms and suggestions enabled me to accomplish the work to this end. My thanks also go to entire members of staff of Agricultural Engineering Department, both academic and non-academic, whose co-operation and assistance during the period of study. Most especially, I wish to thank Mal. Mohammed S. Suleiman of Agric. Engineering Federal University of Technology Minna, his assistance during the period of the project by providing vital information concerning my project area.

Finally, I acknowledge my colleagues and friends Mr. Fabunmi, a staff of the department, Ismaila and Tajudeen both were 500 level students in the department, who worked with me on the field. Their co-operation and assistance throughout the period of this work ,that made the journey smooth and successful. To God be the glory.

ABSTRACT

An investigation was carried out to determine the ground water fluctuation trend, in Gidan Kwano about 15km South of Minna city at the Federal University of Technology (farm) permanent site. The field data collection covered a period of nine (9) months, March to November. The ground water level ranged from 1.62m below the ground surface to 0.27m above the ground surface for the period under consideration. The lowest water level was in the month of September, while the highest water level was in the month of April. Hooghoudt's simple formula was used in developing the groundwater fluctuation models from three separate wells. The validity of the models have been tested using simple linear regression method that give the values of regression coefficient as $b_A = 0.96$ $b_B = 0.94$ $b_C = 0.69$ which is a clear indication that the predicted models is closely mimic the values. The relatively high values correlation coefficient (μ) obtained are; $\mu_A = 0.89$, $\mu_B = 0.86$ and $\mu_C = 0.75$ which also indicate the closeness between the estimated predicted values and the observed points.

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CHAPTER ONE

INTRODUCTION

1.1 General

Ground water levels follow an annual cycle as result of seasonal variation in the quantity of effective or excess rain in the recharge area. Once aquifers have been located and their physical properties assessed, the data may be presented in the form of maps. Typically, maps would be prepared showing the variation of the coefficient of storage and transmissivity in the study area. These factors partially determine the easy with which groundwater level fluctuates, hence such maps are useful in helping to locate potential well sites, (Hamill and Bell, 1986).

Model is usually, to aid in explaining, understanding, or improving a system. The functions of a model are usually considered to be those of prediction and comparison to provide a logical way to forecast the outcomes the follow alternative actions and hopefully, to indicate a preference among them. By introducing a precise framework, a model can serve as an effective means of communication and an aid to thought and experimentation. Any groundwater fluctuation model is only as good as the data upon which it is based. In general, the data that are available initially, the better will be the completed model. This is true regardless of what type of model is developed. The routine monitoring of groundwater level, water quality and soil physical properties are fundamental part of aquifer management. Not only does this provide an early warning system for pollution incidents and phenomena, such as, ground water over-abstraction, included infiltration and salt water intrusion, it also provides essential background data that may be required for comparison purposes, as well as information that is vital to the effective management of the aquifer. Most groundwater fluctuation models require data relating to the following if they are to effectively simulate the aquifer system:

1) Water levels fluctuations in the aquifer over a number of years.
2) The spatial variation of the coefficients of transmissivity and storage.
3) General background information regarding the hydrogeology of the region such as areas of interconnection between surface and groundwater, inter flow between aquifers.

1.2 Justification

As far as groundwater resources is concerned, must be to ensure that an acceptable supply of water can be economically and continuously maintained at a rate approximately equal to the demand. Often there may be more than one way of achieving this objective, in which case some form of computer modelling or optimization technique may be adopted (Hamill and Bell, 1986). Groundwater modelling techniques may also be of value in determining the nature and significance of potential problems associated with, various management options.

1.3 Objectives

The objectives of this study are as follows:

1. To monitor the groundwater fluctuation
2. To use the information obtained to develop groundwater fluctuation model for the university farm.

CHAPTER TWO

LITERATURE REVIEW

2.1 Types of Models

The types of models that may be employed in a modelling study can be grouped into Iconic models, Analogue models, and Mathematical models. Iconic models are actual physical representations and a distinguishing characteristic of such a physical model is that it in some sense "looks like" the entity being modelled. Physical models may be full- scale, scale down or scaled up. They may also be two or three-dimensional.

Analogue models are those in which a property of the real object is represented by a substituted property that often behaves in a similar manner. The problem is often solved in the substituted state and answer, translated to the original properties. The slide rule is an excellent example of an analogue simulation model in which the measured property is represented by logarithmic lengths along a scale. Analogue models are sometimes referred to as schematic representation of flow processes and dynamic operations. A graph is yet another analog model as well as monographs.

Mathematical or analytical models are those in which a symbol, rather than a physical device, is used to represent an entity. Thus, in a Mathematical model, we might use symbols such as x and y to represent production volume and cost instead of a measured scale or some physical entity, which is purely the type of model used in this project. This can as well be called Behavioral model.

(A) Descriptive Models – these are used to present the relationships, order, and sequencing of the systems, and systems components, activities, or analysis with the engineer is involved on a particular problem. More specifically, the engineer uses descriptive models to describe the manner in which something is accomplished as well as for the detailed specification of what is involved. The descriptive model, thus, provides the framework for his efforts.

B) Behavioral Models – these are used to represent the response of a segment of reality to an initial disturbance. In analysis and design, they are used to design components for a given response or to determine the system response given the properties of the components and the system structure.

) Decision Models – decision models are used to select most favorable solution from among the alternatives that are available according to criteria that the engineer establishes. They are used to investigate and resolve conflicts and to select the best alternative and strategies. (Opera, 1987).

A model is a simplified representation of a complex a system, ydrological model (that is, models of hydrological system) being ther:

(a) Physical, such as scale-down facsimile of the full-scale prototype (Chow, 1967).

(b) Analog model such as, the resistance capacitance analog of a coastal aquifer, used by Hunter Blair (1966), and of a complete River Basin, by Ishihara and Ishihara (1961); or Mathematical; in which, the behaviour of the system is represented by a set of equations, perhaps, together with logical statements, expressing relations, between variables and parameters. Choosing a function f(x) sufficient for the purpose in hand is the art of Mathematical modeling.

2.2 Classification of Models Used in Groundwater Table Fluctuation

Although models are extremely numerous and quite diverse in form, it is possible to group them into certain categories according to their objective or function as follows:-

2.2.1 ***Prediction Models***; Generally, simulate groundwater flow in an aquifer. They require information on aquifer characteristics, boundary conditions and pumping rates, while they yield data regarding the direction and rate of groundwater flow changes in water level, surface groundwater interconnection and the effects of abstraction.

2.2.2 ***Resource Management Models***; can be used in tandem with prediction models, include optimization as well as simulation techniques. This type of model is designed to indicate the best course of action to achieve a particular objective, such as minimizing cost or ensuring the maximum rate of supply.

2.2.3 ***Identification Models***; Determine input parameters for both of the above types. Any model is only as good as data upon which it is based. Thus identification models are used to determine the hydrologeological inputs parameters for other models from observations of field data. The example given the rate of abstraction from a well and drawn-down data for several nearby observation holes, it is a relatively simple matter to change the hydraulic characteristics of the aquifer in the model until it responds in a similar fashion to the prototype. These values can then be used, in a prediction models, which would simulate the effect of pumping the well in a manner or at a rate for which no field data exist.

2.2.4 ***Data Manipulation Models***; These handle the data collection networks, process the field data, identify critical data, determine the impute to other models and store all relevant data.

2.3 Modelling of a System (Aquifer)

As the aquifer becomes fully developed (i.e. abstraction roughly equals the recharge) then the need to optimize the management of the groundwater resource naturally leads to the adoption of model to predict consequences of different groundwater level (Ross, 1972).

2.4 Model Formation

A model is usually formulated with respect to a point in time, that is to say, the period over which the data is collected. The model will thus be a static one, which is however, suitable for other periods of time once the relevant data are used, (Opera, 1987).

Given the data recorded of a system input and output up to the present time t, a conceptual model may be used to provide forecasts of future output. If the conceptual model has form similar to that given by equation, such as:

$$y_t = f^* (x_t, x_{t-1}, x_{t-2} \ldots; \Theta_1, \Theta_2 \ldots) + \varepsilon_t \ldots\ldots 2.1$$

Where, as before f^* (.) is a function whose form is given, but having parameters Θ_1, Θ_2.... to be evaluated by measurement or calculation; and ε_t is a residual expressing lack of fit between observed output y_{t+1} and fitted output f^* (.). Choosing this function f^* (.) is sufficient for the purpose of this project and its known as act of mathematical modelling, (Ross, 1972).

2.5 Vegetation

Vegetation in the study area consists of broad leaves Savannah wooden land with some of these trees reaching 10m in height. Along some river courses and some low land areas, the vegetation becomes more wooded and acquires some forest affinities. Generally, however, the predominant vegetation consists of shrubs and grasses (Adesoye and Partners, 1999).

2.6 Land Use

The crops grown in this area are; predominantly yam and sorghum (guinea corn). However, rice, maize and cassava are also cultivated around in the area. presently, farming in this area is rain fed as no dry season farming has started.

2.7 Formation of the Project Area

The site is underlain basement rock of pre-cambrian age, which is granite in nature. The basement rocks occurs in the Northern, central and Southern parts of the site. Since this area is underlain by basement rock of Precambrian age, ground water will be expected in the weathered and fracture parts. Geophysical investigation in this area reveals that the over burden (weathered) part is not very thick aquifer to accumulate water that can sustain a borehole. However, there are evidences of fractures in the rock which most often than not contain enough water that can sustain a bore hole, Fig. 3.8 (Adesoye and Partners, 1999).

2.8 **Topography of the Project Area**

The study area lies between an elevation of 150m in the South and 340m above sea level in the Northern part. The Southern and central parts of the site are typified by a relatively flat and monotonous landscape underlain by biotitie horn-blade granite and granite gries with a few scattered out crops. The major topographic prominence in the area is the Garatu hill located to the Southern corner. It rises to a height of 240m above sea level. The Northern part is remarkable for its alternating rugged and undulating landscape ((Adesoye and Partners, 1999).

CHAPTER THREE

MATERIALS AND METHODS

3.1 General Introduction

This chapter focuses on the methodology by which the project was carried out, such as; survey work, boring of the hand-bored wells, installation of perforated polyvinyl chloride pipes in the hand bored wells, the measurement of ground water level fluctuation, choice of materials used to develop model for the project area. The equations used are:

Hooghoudt's simple formula

$$q = 8kd/L2\ .h \text{ -------------- } 3.1a$$

and Zeeuw and Hellinga formula

$$h_t = h_{t-1}\, e^{-\propto\partial t} + \frac{R_{\partial t}(1-e^{-\propto\partial t})}{0.8\mu\propto} \text{ ----- } 3.1b$$

The site is located along Minna-Bida road at about 15km to Minna. The field is an inland valley of which covers a land area of about 13,859.1 m^2 (1.4ha.). Survey work was carried out along the existing stream in the area, (Fig. 3.3).

A straight line was set out across the valley using 3,4,5 method as seen in section A-A shown in figure 3.3. This same line was then used to determine the contour map of the area using dumping level.

3.2 Model Development

3.2.1 Hooghoudt Formula (Steady State)

A steady state drain spacing formula for pipe drainage was developed in 1940 by the Netherlands drainage researcher Hooghoudt. In this formula only the headlosses due to horizontal and radial flow to the pipe are considered, losses due to vertical flow usually being insignificant). Hooghoudt conceived that a parallel open ditch system with the ditches reaching to the impermeable substratum, could generate the same discharge (q) for the same watertable head (h) as an identically spaced pipe drain system by reducing the depth (D) to the impermeable substratum. This led him to the idea to treat the horizontal radial flow to pipe drain (described by the rather complex equation 3.2)as an equivalent flow to ditches with the impermeable base at a reduced depth (d). This equivalent flow is essentially horizontal and may be described by the simpler equation 3.3

- real flow (horizontal + radial)

$$h = h_h + h_r = \frac{qL^2{}_h + qL}{8KD_h} \frac{\ln aD_r}{\pi K\mu} \qquad \text{---------- } 3.2$$

- equivalent flow (horizontal)

$$h = h_{h*} \text{ (equivalent) } = \frac{qL^2}{8KD_{h*}} \qquad \text{---------- } 3.3$$

Since d<D, less cross-sectional flow area is available and consequently more head is lost in the horizontal flow in the equivalent case than in the real case, the difference just equalling the headloss over the radial flow zone in real case.

The average thickness of the equivalent horizontal flow may be approximated as

$D_{h*} = d + h/2$ when inserted in equation 3.3 gives

$$h = \frac{qL^2}{8K(d + h/2)} \quad \text{or} \quad q = \frac{8kh\,(d + h/2)}{L^2} \qquad \text{---------} \; 3.4_a$$

$$q = 8kdh/L^2 + 4kh^2/L^2 \qquad \text{------------} \; 3.4_b$$

The equivalent horizontal flow takes place partly below the drainage base (average thickness)of this flow zone being, d and partly above the drainage base (thickness of this flow zone being h/2). These two flow components are respectively represented, by the first and second term in equation 3.4b. When the flow above drainage base has a different hydraulic conductivity (K_1) than below (K_2), this may be taken into account.

$$q = 8k_2dh/L^2 + 4k_1h^2/L^2 \qquad \text{------------} \; 3.5$$

3.2.2. Notes on the Hooghoudt Formula

1. The Hooghoudt formula shows that, (all other variables remaining constant), the spacing L increases when.
   - K increases (especially when K_2 increase; the value K_1 has much less effect on L)
   - q decreases ($L \sim q^{-1/2}$)
   - D increase (has less influence when L is small than when L is large)
   - h increase (implies of decrease or increase of H).
2. When the drainage flow above the drainage base may be neglected, the Hooghoudt formula reduces to:

   $L^2 = 8kdh/q$ (simple Hoogoudt formual) -------------------3.6

3. A change in hydraulic conductivity at about drainage base depth is quite common in non stratified soils.
4. Where a significant vertical flow is been expected and the relevant flow zone has a very low hydraulic conductivity, $(h-h_v)$, instead of h should be used in the Hooghoudt formula, with h_v determine according to equation.

   $h_v = qD_v/k$ --3.7

5. The second part of Hooghoudt formula ($q = 4kh^2/L^2$, see equation 3.4a) applying to the flow to the drain from above the drainage base should not be applied separately. When, the drainage base coincides with impermeable base, so that all occurs above the drainage base, the Fukuda Formula is applicable

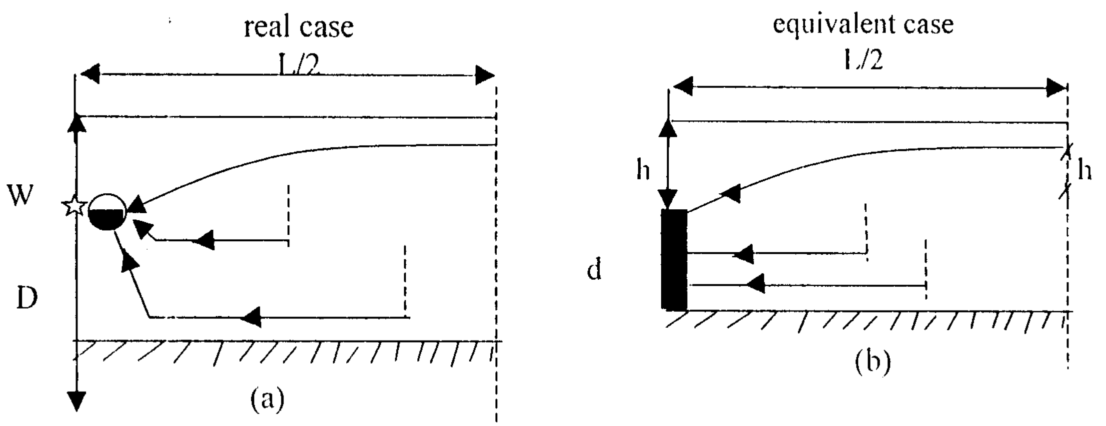


Fig. 3.1 Transformation Underlying the Hooghoudt Formula

Fluctuating Watertable (de Zeeuw and Hellinga Formula)

Hooghoudt's simple (equation 3.6) was developed to show the non-steady response to periodic rainfall or irrigation. In this equation the drain discharge (q) is

$$q = 8kd.h/L^2 \tag{3.8}$$

The variation of the drain discharge with time is thus also linearly related to the variation in time of the watertable head.

$$\frac{dq}{dt} = \frac{8kd}{L^2} \frac{dh}{dt} \tag{3.9}$$

If the groundwater body is recharged by rainfall or by another source (R) and is depleted by drain discharge (q), it follows that the watertable will rise when $(R-q)>0$ and fall when $(R-q)<o$. By analogy with equation 3.8 the watertable fluctuation may be described by:

$$dh/dt = (R - Q)/C\mu \tag{3.10}$$

Combining equation 3.10 and 3.9 and taking $C = 0.8$, gives:

$$dq/dt = (10kd/\mu L^2)\,(R - q) = \alpha\,(R - q) \tag{3.11}$$

in which $\alpha = 10^{*}kd/\mu L^2$ obtained from Glover Dumm's equation

$$h_t/h_o = 1.16e^{-\alpha t}$$

So that change in drain discharge (dq/dt) is proportional to the excess recharge (R – q), the constant of proportionality being (reaction factor, (see equation (3.12)).

Integrating equation 3.11 between the limits t = t q = q_t and t = t-1: q = q_{t-1} gives.

$$\int_{q_{t-1}}^{q_t} dq/R - q) = \int_{t-1}^{t} \alpha dt \text{ ------------ } 3.12$$

$$\ln (R - q) \Big]_{t-1}^{t} = \alpha t \Big]_{t-1}^{t} \text{ ------------ } 3.12a$$

$$-\{\ln (R - q_t) - \ln (R - q_{t-1})\} = \alpha (t - t+1) \text{------- } 3.12b$$

$$\ln(R - q_{t-1}) - \ln(R - q_t) = \alpha(0 + 1) \text{ ------------ } 3.12c$$

$$\ln \{(R - q_{t-1})/(R - qt\} = \alpha\Delta t \text{ ----------------} 3.12d$$

$$R = q_t = (R - q_{t-1})\, e^{-\alpha\Delta_t} \text{ ------------------- } 3.12e$$

As bracket open to give

$$R - q_t = Re^{-\alpha\Delta_t} - q_{t-1}\, e^{-\alpha\Delta_t} \text{ ------------------- } 3.12f$$

$$- q_t = -q_{t-1}\, e^{-\alpha\Delta_t} \ (Re^{-\alpha\Delta_t} - R) \text{ multiply by } - 1$$

$$q_t = q_{t-1}e^{-\alpha\Delta_t} + (R - Re^{-\alpha\Delta_t}) \text{ ------------------- } 3.12g$$

Factorizing eq. 3.12g to give

$$q_t = q_{t-1}e^{-\alpha\Delta_t} + R(1 - e^{-\alpha\Delta_t}) \text{ ---------------- } 3.13a$$

Since $q = 0.8\mu\alpha h$

Substituting the q in equation 3.13a to give

$$0.8\mu\alpha h = 0.8\alpha\mu h_{t-1}\, e^{-\alpha\Delta t} + R^{\Delta t}) \text{ ----------------- } 3.13b$$

divided 3.13b by 0.8$\alpha\mu$ to give

$$h_t = h_{t-1}\, e^{-\alpha\Delta t} + \frac{R_{\Delta t}(1-e^{-\alpha\Delta t})}{0.8\mu\alpha} \text{ ----------------- } 3.14$$

Where:-

t = time (days)

h_o = initial watertable head at $t = t_o$ (m)

h_t = watertable head at $t =$ (m)

α = reaction factor (days^{-1})

μ = drainable pore space (m^{3}m-3)

The factor 10 is actually x^2 (9.84)

δt = change in time (week)

In which $R_{\Delta t}$ is the mean value of R during the time interval t –1 to t is assumed constant. Using the linear relationship q and h of equation 3.6 ($q = 8kd/L^2\, h = 0.8\alpha\mu h$). Figure 3.2 outlined the method used in determination of reaction factor (α)

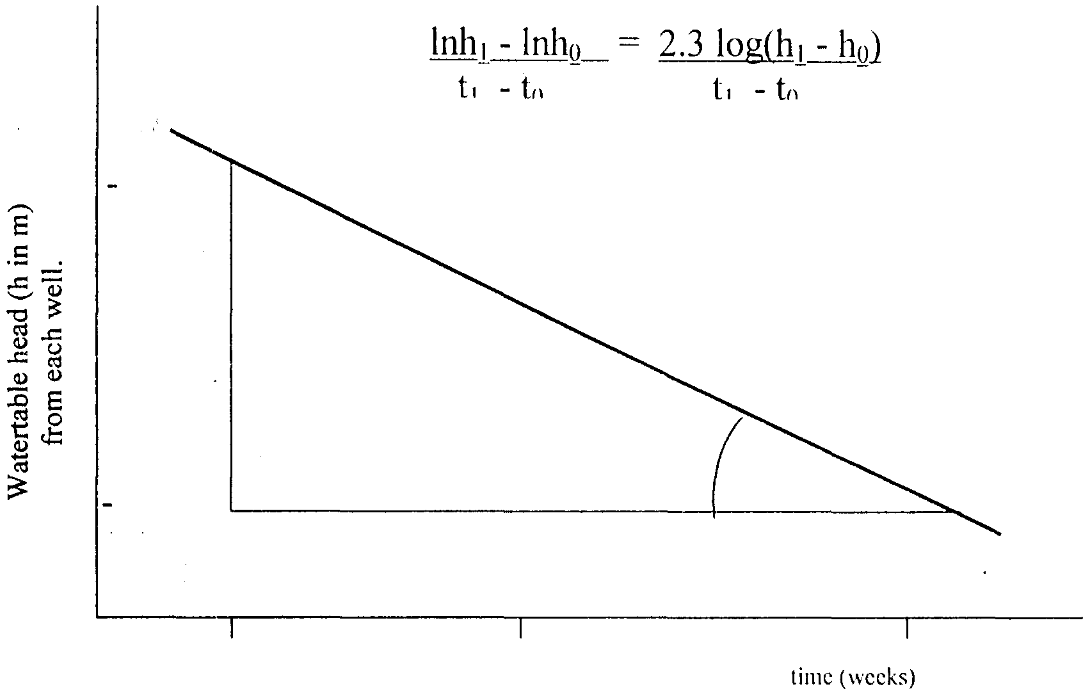


Figure 3.2: Determination of the Reaction Factors from Observed Watertable Heads.

3.2.3 **Sample of Calculation of Pore Space (μ)**

Having obtained the value α, it was then substituted in equation 3.14 to obtain the values of pore space (μ).

Using the equation (3.14) below for Well A

$$h_t = h_{t-1}\, e^{-\alpha\delta t} + R_{\delta t}(1 - e^{-\alpha\delta t})/(0.8\mu\alpha)$$

Well (A)

The estimated reaction factor (α) from Table 3.4 is 0.24 as at week 24 and $h_t = 0.26$

Substituting the known parameter in equation 3.14

$$0.26 = 0.26(e^{-0.24}) + \frac{0.008}{0.8 \times 0.24\mu}(1 - e^{-0.24 \times 1})$$

$$0.26 = 0.205 + \frac{0.042 \times (0.21)}{\mu}$$

$$0.009/\mu = 0.055$$

$$\mu = 0.009/0055 = 0.16$$

Well B

The estimated reaction factor for well B is 0.11 substituting the reaction factor value in equation 3·14 and the other known values.

At week 23 t = 23 ht = - 0.52

$$0.52 = +0.92\,(e^{-0.11}) + \frac{0.008}{0.8x0.11x\mu}\,(1 - e^{-0.11})$$

$$+0.52 = +0.824 + \frac{0.0095}{\mu}$$

$$+0.52 = +0.824 + = \frac{0.095}{\mu}$$

$$0.304 = -0.0095$$

$$\mu = -0.0095/0.304 = -0.031$$

WELL C

The estimated reactor factor for Well C is 0.064 substituting the reactor factor value in equation 3.14 and other known values.

At week 27 t =22 ht = 0.74

$$h_t = h_{t-1}\,(e^{-0.64}) + \frac{0.008(1 - e^{-0.64})}{0.8x0.064 \text{ x } \mu}$$

$$-0.74 = -0.7 \text{ x } 0.38 + \frac{0.0096}{\mu}$$

$$-0.04580 = \frac{0.0096}{\mu}$$

$$\mu = \frac{0.0096}{0.0458} = -0.201$$
$$= -20\%$$

$\mu_{(a)} = -16\ \%$; $\mu_{(b)} = 3\%$; $\mu_{(c)} = 20\ \%$

The values of $\mu_{(a)}$, $\mu_{(b)}$ and $\mu_{(c)}$ were substituted in equation 3.14 to give the following equations.

The derived equation (models)

(i) $h_t = h_{t-1}e^{-0.24^{\delta}t} + R_{\delta t} / 0.031\ (1 - e^{-0.24^{\delta}t})_{\text{well (a)}}$ 3.15

) $h_t = h_{t-1}e^{-0.11^{\delta}t} - R_{\delta t} / 0.0027 \left(1 - e^{-0.11^{\delta}t} \right)_{\text{well (b)}}$ ……………3.16

i) $h_t = h_{t-1}e^{-0.064^{\delta}t} - R_{\delta t} / 0.0104 \left(1 - e^{-0.064^{\delta}t} \right)_{\text{well (c)}}$ ……………3.17

3 **Well Boring**

Hand driven soil auger of about 4.0m long, with diameter of 5cm cally produced was used to drill the wells (Fig. 3.5). The wells were at 0m intervals each having piezometric tube.

The Figure has been Scale down from 100% to 70% in size on the photocopy machine

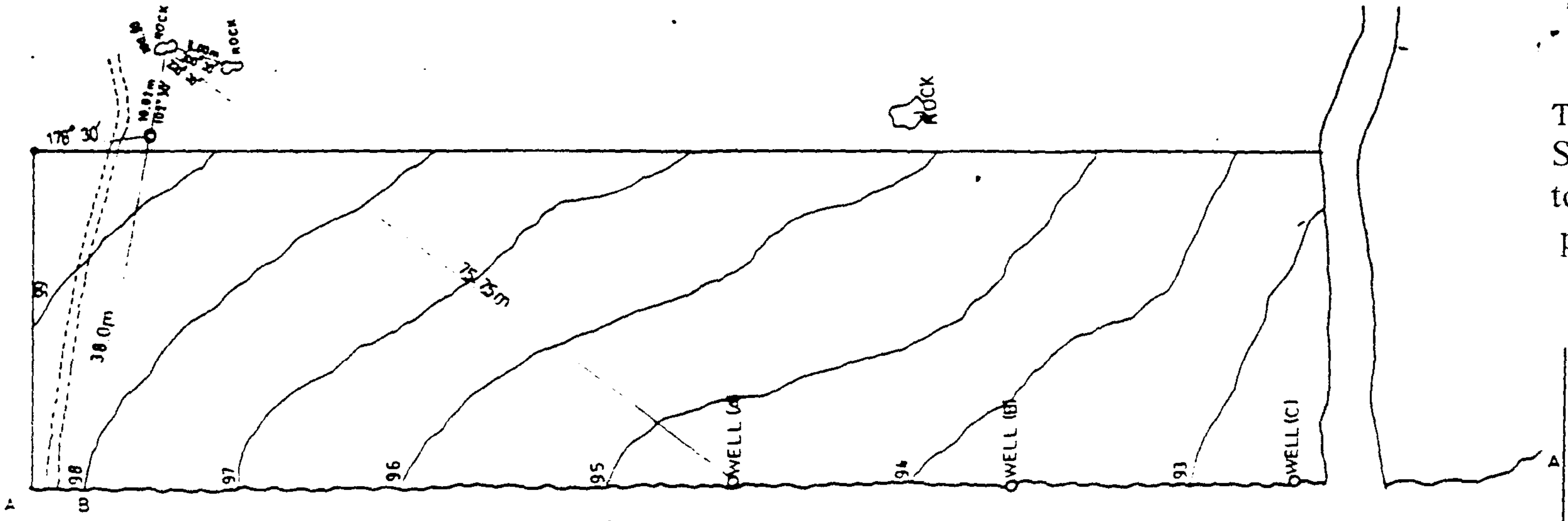


FIG 3.1A VALLEY SECTION

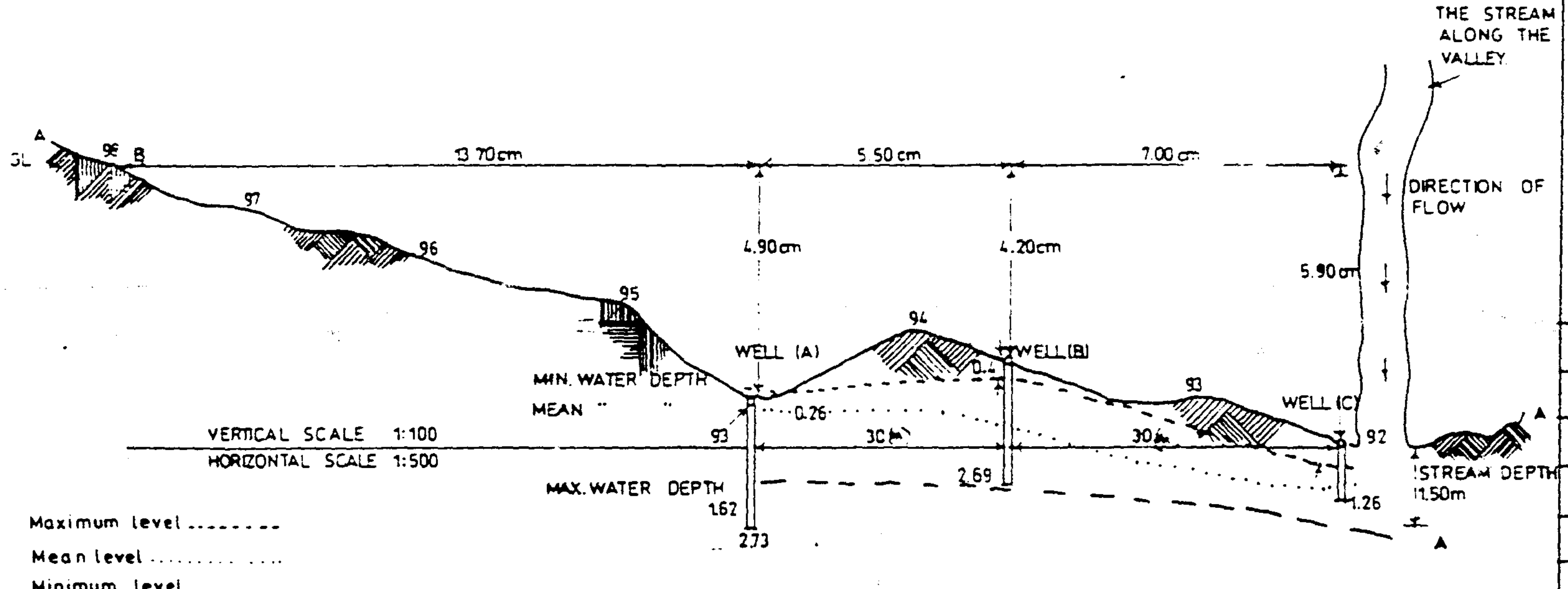
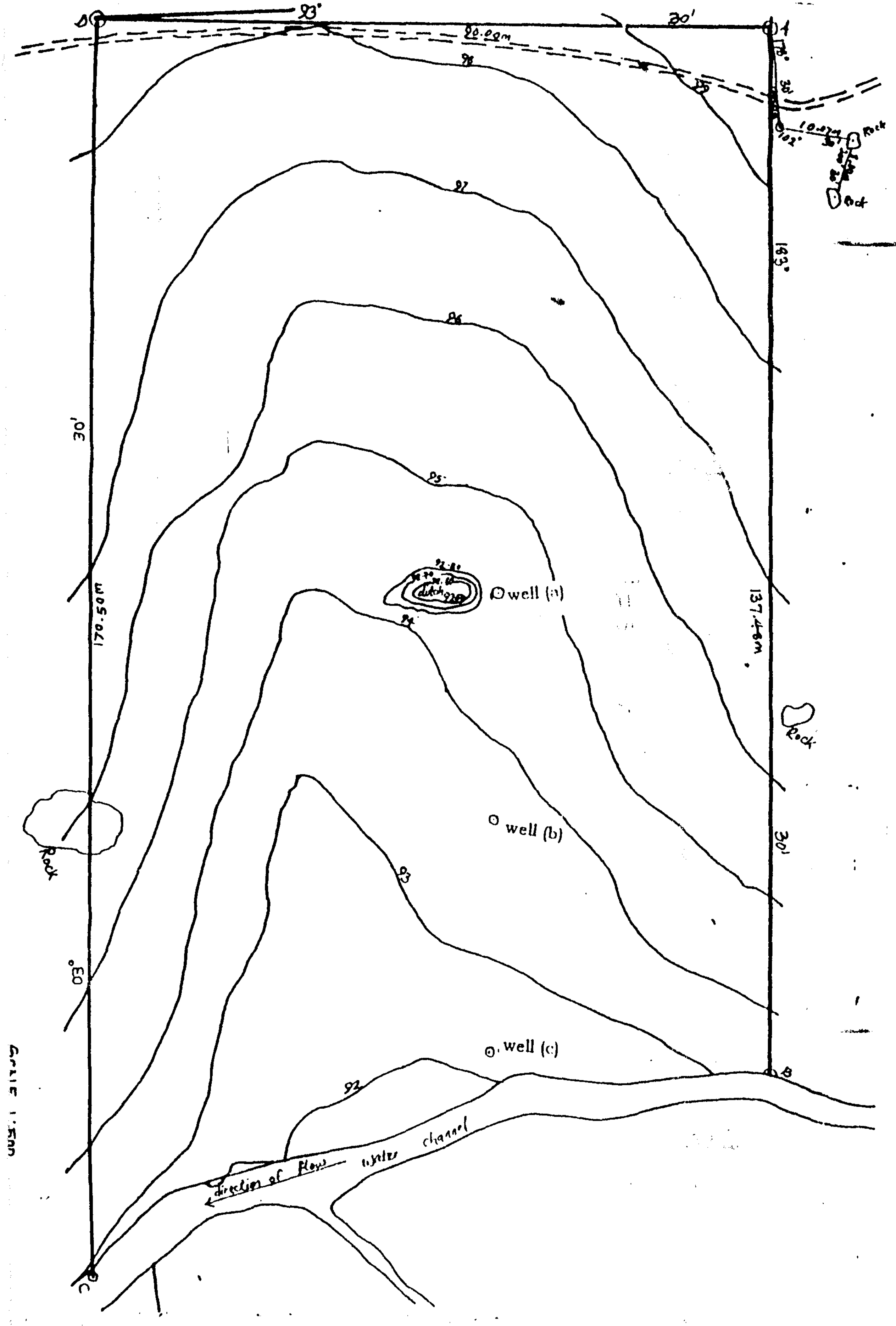


FIG. 3.3 GROUNDWATER LEVEL CONTOUR MAP WITH RELATIVE POSITIONS OF EACH WELL TO A REFERENCE POINT B



Contour Map of the Project Area

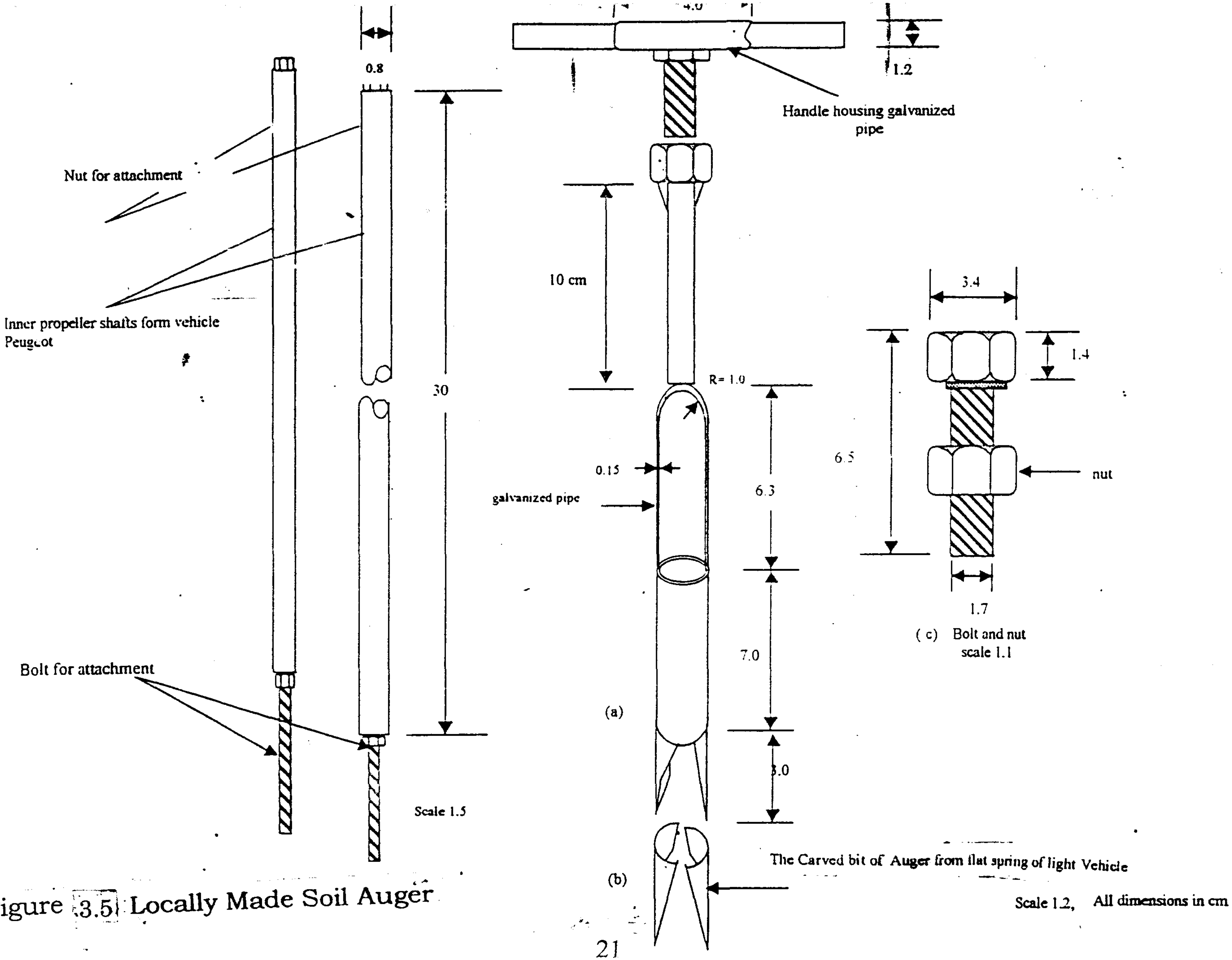


Figure 3.5 Locally Made Soil Auger

3.3.1 **Piezometric pipes**

The piezometric pipes are of 45mm inner diameter and about 3m in length. All the pipes were radially perforated at 2cm apart across the length of the pipe to allow sufficient and effective inflow of ground water into the pipes to assume its original level (Fig. 3.6).

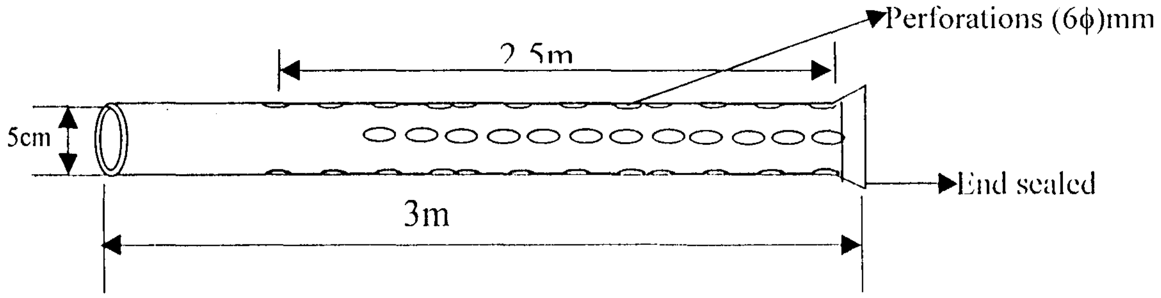


Figure 3.6: Piezometric Pipe

3.3.2 **Installations of Piezometric Pipes**

The pipes were buried vertically with their perforated edges below the ground surface but about 15cm projected out of ground surface. At the neck of the pipes on the ground surface, the clearances between the wells and the pipes were sealed using concrete mix, to disallow the vertical flow of water into the wells, by run - off or precipitation incase of any rainfall occurrence (Fig.3.7). In the bored holes a radially perforated polyvinyl chloride pipes were installed to prevent the wall of the bored holes from collapsing and blockage.

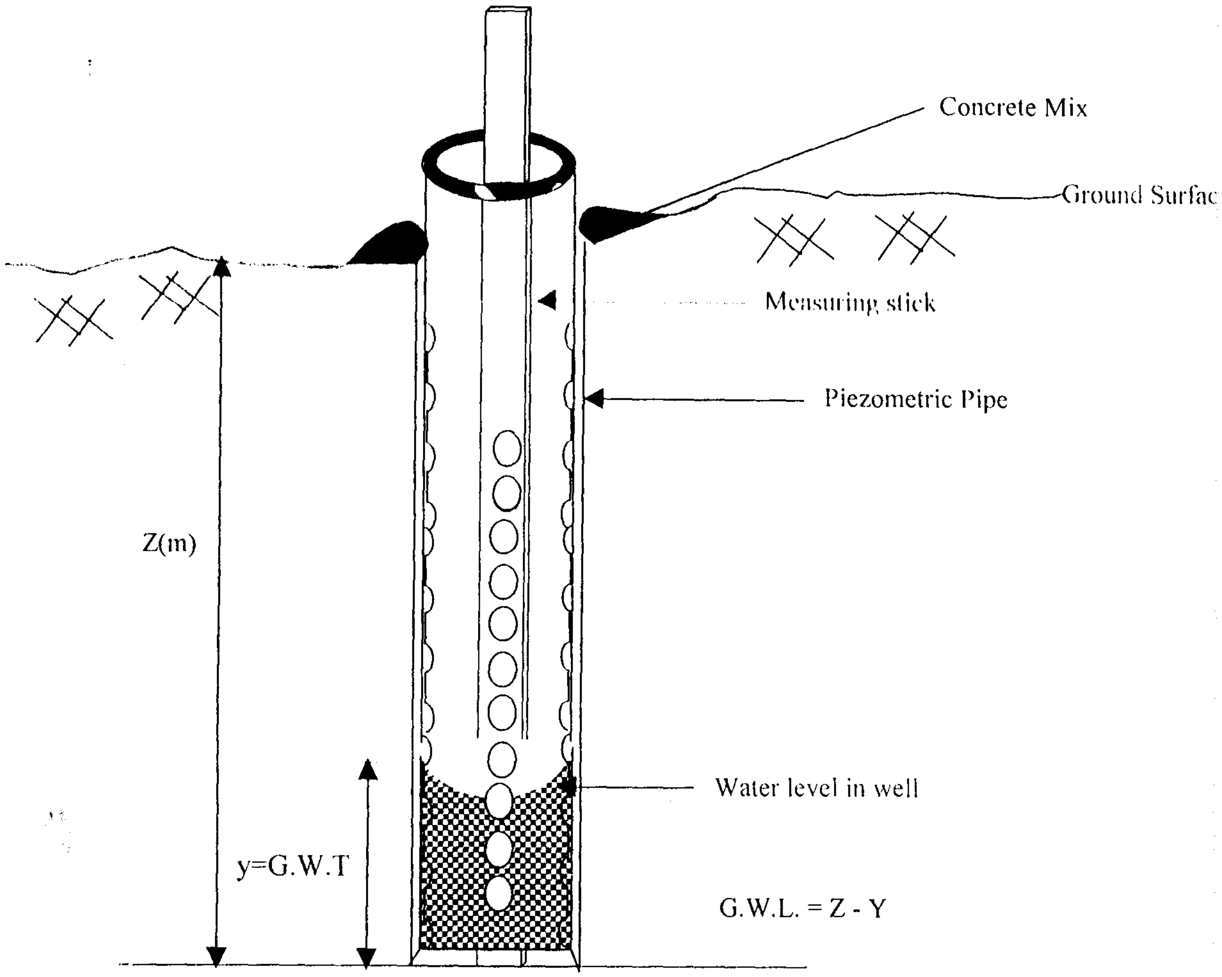


Figure 3.7. Cross Section of the pipe in well

3.3.3 **Measurement of Groundwater Level Fluctuations**

Three (3) straight long wooden plank (Dip-Stick) ruled on the edges along the length were inserted in the installed pipes ensuring that they touched the bottom of the pipe. The stick were three in number in order to avoid contamination, they were used one after the other, each stick for its own well and allowed to stay for reasonable time (about 1 minute), so that the water in the pipe wets the wooden plank. The wetted points were held against the standard meter and read each time as height of water in well. These were then subtracted from Zcm to give the actual reading i.e. level of water beneath ground surface, (Fig. 3.7). This was done at interval of one week for 9 months.

3.4 Climatic And Soil Condition of The Experimental Site

Rainfall in the area occurs generally between the month of April to October and reaches its peak normally in August. The mean annual rainfall is about 1338 mm. The relative humidity varies all year round but generally it rises to over 80% in the morning and falls to between 50% and 70% in the afternoon during the wet season. The average air temperature of the study area is about 27°C with the temperature rising to its peak to about 36°C in March. The temperature drops to about 25°C during the peak rainfall in August, (Tables 3.1-3.3). Sunshine in the study area is relatively high during the month of December to March. The area, is affected by two principal wind currents, which occurs between November to February. The dry wind which brings hamattan dust from the Sahara desert, and as the raining season sets in the later part of April, the wind shift to the South bringing moist air and cloudy condition with thunderstorm. (Muhammed 2000).

The soil condition of the experimental site are presented in appendices A-H.

TABLE 3.1 TOTAL MONTHLY RAINFALL {mm} {1991-2001} FOR MINNA

YEAR	JAN.	FEB.	MAR.	APL.	MAY.	JUN.	JULY.	AUG.	SEP.	OCT.	NOV.	DEC.
1991	0.0	TR	TR	14.50	336.00	180.10	192.90	218.50	190.80	33.90	0.00	0.0
1992	0.00	0.00	0.00	1.30	158.20	176.80	162.90	196.40	231.50	230.30	46.60	379.5
1993	0.00	0.00	0.00	0.00	174.40	170.50	189.70	271.10	178.30	63.30	XX	0.00
1994	0.00	0.00	7.30	72.50	114.40	239.00	142.50	367.20	261.30	208.10	0.00	0.00
1995	0.00	0.00	0.00	100.50	123.20	144.50	153.70	409.00	189.10	135.70	236.00	0.00
1996	0.00	0.00	0.00	48.60	164.70	225.00	259.70	257.00	191.10	127.90	0.00	0.00
1997	0.00	0.00	3.60	80.60	238.40	233.00	172,40	192.90	273.30	115.00	6.10	0.00
1998	0.00	0.00	TR	92.20	121.20	221.00	155.50	243.00	261.90	212.60	0.00	0.00
1999	0.00	7.90	0.00	35.70	102.80	164.20	243.90	254.70	237.10	212.20	0.00	0.00
2000	0.00	0.00	0.00	3.60	135.90	161.00	208.80	308.50	303.00	153.40	0.00	0.00
2001	0.00	0.00	0.00	93.90	139.00	331.70	244.60	230.20	298.80	25.70	0.00	0.00
TOTAL	0.00	7.90	10.89	543.40	1808.40	2247.30	2126.30	2939.20	2615.80	1518.00	288.20	379.50
MEAN	0.00	0.72	0.99	49.40	164.40	204.30	193.30	267.20	237.80	138.00	26.20	34.50

Source: Dept. of Meteorological Services, Fed. Min. of Aviation, Minna Airport, Niger State, (2002)

TR= trace of rainfall.

Table 3.2 : Monthly Relative Humidity {%} {1991-2001} FOR MINNA

YEAR	JAN.	FEB.	MAR.	APL.	MAY.	JUN.	JULY.	AUG.	SEP.	OCT.	NOV.	DEC.
1991	27.00	51.00	49.00	69.00	81.00	95.00	88.00	90.00	81.00	77.00	46.00	34.00
1992	28.00	25.00	55.00	68.00	76.00	82.00	87.00	88.00	83.00	77.00	49.00	38.00
1993	33.00	40.00	53.00	63.00	72.00	80.00	86.00	86.00	81.00	71.00	XX	44.00
1994	40.00	25.00	55.00	63.00	74.00	80.00	84.00	87.00	85.00	76.00	45.00	30.00
1995	34.00	27.00	48.00	62.00	72.00	77.00	81.00	86.00	80.00	73.00	39.00	34.00
1996	33.00	42.00	57.00	63.00	73.00	81.00	87.00	85.00	84.00	74.00	32.00	31.00
1997	31.00	18.00	46.00	64.00	70.00	82.00	85.00	85.00	82.00	78.00	45.00	28.00
1998	32.00	32.00	25.00	61.00	76.00	80.00	86.00	87.00	83.00	77.00	47.00	36.00
1999	31.00	36.00	58.00	57.00	70.00	78.00	84.00	81.00	82.00	79.00	50.00	33.00
2000	40.00	25.00	34.00	63.00	69.00	-	85.00	87.00	84.00	74.00	45.00	33.00
2001	31.00	30.00	44.90	57.00	61.00	70.00	76.00	79.00	73.00	52.00	43.70	35.60
TOTAL	359.70	351.12	524.92	689.7	794.20	805.20	929.00	949.30	897.60	803.00	442.20	376.20
MEAN	32.7.00	31.92	47.72	62.70	72.20	73.20	86.30	85.50	81.60	73.00	40.20	34.20

Source: Dept. of Meteorological Services, Fed. Min. of. Aviation, Minna Airport, Niger State, (2002)

TABLE 3:3 TOTAL MONTHLY TEMPERATURE (^{o}C){1991-2001} FOR MINNA.

YEAR	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JULY.	AUG.	SEP.	OCT.	NOV.	DEC.
1991	28.50	31.00	31.65	30.00	27.40	25.90	25.60	26.00	26.65	27.15	27.30	27.40
1992	26.55	29.35	31.15	29.55	28.25	26.30	25.65	25.30	25.55	27.15	27.30	27.40
1993	26.65	27.60	30.40	31.50	29.40	26.85	25.70	25.55	25.50	27.25	Xxx	27.65
1994	27.25	29.90	32.20	30.50	28.45	26.65	26.05	25.25	25.80	26.20	26.70	26.45
1995	26.75	29.40	31.95	31.30	28.40	27.10	26.10	25.40	26.10	26.95	27.15	26.75
1996	27.75	30.25	31.60	31.30	28.05	26.00	25.25	24.70	25.45	25.95	26.25	26.70
1997	28.20	28.35	30.85	29.80	27.50	26.60	25.85	26.30	26.20	26.85	27.20	26.90
1998	27.35	31.15	32.25	32.35	28.95	27.10	26.10	25.35	25.95	26.95	27.80	27.65
1999	28.05	29.90	32.05	31.65	28.95	27.05	25.70	25.35	25.70	26.95	27.65	27.25
2000	28.70	28.60	31.70	31.75	30.50	26.25	25.60	25.20	25.95	26.95	27.10	26.65
2001	27.65	29.95	31.55	30.35	28.95	26.40	25.55	25.00	25.20	27.05	26.55	27.50
TOTAL	303.38	325.49	347.38	339.90	314.82	293.37	283.8	278.96	283.36	293.7	271.15	297.77
MEAN	27.58	29.59	31.58	30.90	28.62	26.67	25.80	25.36	25.76	26.70	24.65	27.07

Source: Dept. of Meteorological Services, Fed. Min. OF. Aviation, Minna Airport, Niger State, (2002)

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Groundwater Level Fluctuation

Ground water fluctuation in Gidan Kwano (School farm) Minna for the year 2001, is shown in (Appendice M). The readings were taken between the months of March and November. All the three Wells were considered for the analysis, it was found that Well (A) contained water throughout the period of observation. At the same time, it had the least depth of water table when compared to wells B and C. In April, the depth of water table was 1.62m below the ground surface. This gradually increased to 0.27m above ground surface, as of month of September. The positive sign in the value shows that, the well (A) over flowed during the period of observation, that is to say there was recharge from surrounding and far distances formation of a higher elevation. Figure 3.3 shows, the depth of each well before reaching a more consolidated formation (rock).

4.2 Estimate of Reaction Factor (α) and Pore Space (μ)

The estimated values of α were obtained by observing the actual response of the system in the field. Observed y values were plotted on lognormal paper against change in time (week). Observation was carried out during periods of low evaporation shortly after the end of a few good raining days when the recharge to the groundwater has ceased and the water table starts receding. The observations from week 30 to week 39 (Appendice M) were used to estimate α. Observed y values were to be plotted on log-normal paper, but was converted to normal graph paper (Fig. 3.2) as follows:-

For well $_{(a)}$ ln0.12 = -2.12 (week 36)

ln 0.63 = -0.42 (week 37)

ln 0.83 = -0.19 (week 38)

ln 0.94 = -0.06 (week 39)

$$\frac{\text{Ln } 0.67 - \text{Ln } 0.25}{39.1-37} = \frac{-0.4+1.4}{39.1-37} = \frac{1.0}{2.1} = \mathbf{0.48}$$

The average values of reaction factors obtained from Table 4.1 to 4.4 are:

Well A = (0.15 + 0.45 + 0.05)/3 = 0.24

Well B = (0.01 + .01 + 0.31)/3 = 0.11

Well C = (0.15 + 0.0155 + 0.086)/3 = 0.0647

Table 4.1: Time and transformed water depth Well A

TIME (WEEK) (t)	Depth (h_t) (m)	In (h_t) -	Reaction factor (α)
1	1.37	-0.31	= 0.15
2	1.40	0.34	
3	1.40	0.34	
4	1.42	0.35	
5	1.51	0.41	= 0.045
6	1.57	0.45	
7	1.62	0.50	
36	0.12	-2.12	= 0.065
37	0.63	-0.46	
38	0.83	-0.19	
39	0.94	-0.06	

Table 4.2: Time and transformed water depth Well B

Time (Week) (t)	Depth (h_t) (m)	In (h_t) -	Reaction factor (α)
1	2.52	0.92	= 0.01
2	2.52	0.94	
3	2.56	0.94	
4	2.57	0.94	
5	2.60	0.96	
12	2.43	0.89	= 0.01
13	2.46	0.90	
14	2.48	0.91	
15	2.56	0.94	
30	0.62	-0.48	= 0.31
31	0.67	-0.40	
32	0.66	-0.42	
33	1.55	0.14	

Table 4.3: Time and transformed water depth Well C

Time (Week) (t)	Depth (h_t) (m)	In (h_t)	Reaction factor (α)
12	0.82	-0.20	= 0.15
13	0.89	-0.12	
14	1.20	0.18	
16	1.17	0.16	= 0.0155
17	1.19	1.17	
18	1.21	0.19	
30	0.65	-0.43	= 0.086
31	0.85	-0.16	
32	0.88	-0.13	
33	0.92	-0.08	

Table 4.4: for best of α values (it was chosen between 36-39)

Well A

Time (Week) (t)	Depth (h_t) (m)	In (h_t)	Reaction factor (α)
36	-0.12	-2.22	
37	0.63	0.46	
38	-0.83	-0.19	= 0.24
39	-0.94	0.06	

Well B

Time (Week) (t)	Depth (h_t) (m)	In (h_t)	Reaction factor (α)
34	-0.71	-0.34	
35	-1.11	0.104	
36	-2.00	0.69	= 0.11

Well C

Time (Week) (t)	Depth (h_t) (m)	In (h_t)	Reaction factor (α)
30	0.65	-0.43	
31	0.85	-0.16	
32	0.88	-0.13	= 0.064
33	0.92	-0.08	

This period (week 30-39) complies with the rules guiding the determination of α of any aquifer by inspection.

$\alpha_{(a)} = 0.24$; $\alpha_{(b)} = 0.11$; $\alpha_{(c)} = 0.064$;

4.3 Model Verification

4.3.1 Predicted Groundwater Table Depth

All the constants obtained through the use of equation 3.14 and other means were substituted back in equation 3.14 which give rise to equation (3.15), (3.16) and (3.17) for groundwater fluctuation in Well A, Well B and Well C, respectively.

WELL A

In week 24 (t = 24) $h_{23} = 0.26$

$$h_{24} = h_{23}\ (e^{-0.24}) + \frac{R_{dt}(1 - e^{-00.24})}{0.031}$$

Substituting the known parameters in above equation

$$h_{24} = 0.26\ (2.72^{-0.24}) + \frac{0.008(1 - e^{-00.24})}{0.031}$$

$$h_{24} = 0.265 + 0.055 = (0.26\text{m})$$

WELL B

At week 26 (t = 26) $h_{25} = -0.6$

$$h_{24} = h_{23}\ (e^{-0.11}) + \frac{R_{dt}(1 - e^{-0.11})}{0.031}$$

Substituting the known parameters in above equation

$$h_{24} = -0.6\ (2.72^{-0.11}) + \frac{0.008}{0.0077}(1 - e^{-0.11})$$

$$h_{24} = 0.54 - 0.309 = -0.84\text{m}$$

WELL C

At week 30 (t = 30) $h_{29} = -0.68$

$$H_{30} = h_{29}\ (e^{-0.064}) + \frac{R_{dt}(1 - e^{-0.064})}{0.0104}$$

Substituting the known parameters in above equation

$$H_{30} = -\ 0.68\ (e^{-0.064}) - \frac{0.008(1 - e^{-0.064})}{0.0104}$$

$$h_{30} = 0.64 - 0.048 = -0.69\text{m}$$

Table 4.5: Groundwater Table Fluctuation Observed and Predicted. **(Well A)**

S. No / time (Week)	PPT (m) $R_{\delta t}$	Y_a (m)	
		Observed	Predicted
1	0	-1.37	-1.78
2	0	-1.40	-1.78
3	0	-1.40	-1.80
4	0	-1.42	-1.91
5	0	-1.51	-1.99
6.	0.001	-1.57	-1.56
7	0.003	-1.62	-1.23
8	0.004	-1.39	-1.26
9	0.004	-1.22	-1.07
10	0.004	-1.20	-0.94
11	0.005	0.25	-0.92
12	0.006	0.17	0.03
13	0.007	-0.21	0.17
14	0.009	-0.9	-0.12
15	0.011	0.23	-0.65
16	0.011	0.25	0.26
17	0.010	0.26	0.27
18	0.010	0.25	0.27
19	0.010	0.20	0.27
20	0.0082	0.26	0.23
21	0.008	0.26	0.26
22	0.008	0.26	0.26
23	0.008	0.26	0.26
24	0.008	0.26	0.26
25	0.008	0.22	0.26
26	0.009	0.26	0.23
27	0.009	0.27	0.27
28	0.010	0.26	0.27
29	0.009	0.22	0.27
30	0.008	0.21	0.23
31	0.005	0.14	0.22
32	0.003	0.03	0.14
33	0.001	0.26	0.024
34	0.001	0.26	0.21
35		0.19	0.21
36		-0.12	0.15
37		-0.63	-0.01
38		-0.83	-0.50
39		-0.94	-0.66
40			

$Y_{(a)}$ = water level in well $_a$

PPT= Precipitation (Rainfall)

$R_{\delta t}$ = Applied Irrigation Water

Negative sign = Depth of water below the ground surface

Table 4.6: Groundwater Table Fluctuation Observed and Predicted.

(Well B)

S. No /time (week)	PPT (m)	Y_b (m)	
		Observed	Predicted
1	0	-2.52	-2.85
2	0	-2.55	-2.86
3	0	-2.56	-2.87
4	0	-2.57	-2.90
5	0	-2.60	-3.21
6	0.001	>-2.69	-2.88
7	0.003	>-2.69	-2.85
8	0.004	-2.55	-2.73
9	0.004	-2.45	-2.44
10	0.004	-2.40	-2.35
11	0.005	-1.76	-2.31
12	0.006	-2.43	-1.78
13	0.007	-2.46	-2.41
14	0.009	-2.48	-2.47
15	0.011	-2.56	-2.57
16	0.011	-2.55	-2.71
17	0.010	-1.50	-2.70
18	0.010	-1.01	-1.72
19	0.010	-1.02	-1.28
20	0.0082	-0.98	-1.29
21	0.008	-0.95	-1.19
22	0.008	-0.92	-1.15
23	0.008	-0.52	-1.12
24	0.008	-0.71	-0.02
25	0.008	-0.60	-0.94
26	0.009	-0.54	-0.84
27	0.009	-0.40	-0.82
28	0.010	-0.50	-0.69
29	0.009	-0.51	-0.82
30	0.008	-0.62	-0.38
31	0.005	-0.67	-0.85
32	0.003	-0.66	-0.79
33	0.001	-1.55	-0.71
34	0.001	-0.71	-1.43
35		-1.11	-0.68
36		-2.00	
37		-2.00	
38		>-2.69	
39		>-2.69	
40			

$y_{(b)}$ = water level in well b

Table 4.7: Groundwater Table Fluctuation Observed and Predicted.

(Well C)

S/No. /time (week)	PPT (m)	Y_c (m)	
		Observed	Predicted
1	0	>-1.69	
2	0	>-1.69	
3	0	>-1.69	
4	0	>-1.69	
5	0	>-1.69	
6	0.001	>-1.69	
7	0.003	>-1.69	
8	0.004	1.25	
9	0.004	-1.23	-1.20
10	0.004	-1.21	-1.20
11	0.005	-1.18	-1.16
12	0.006	-0.82	-1.14
13	0.007	-0.89	-0.81
14	0.009	-1.20	-0.88
15	0.011	-1.18	-1.18
16	0.011	-1.17	-1.17
17	0.010	-1.19	-1.16
18	0.010	-1.21	-1.18
19	0.010	-0.84	-1.20
20	0.0082	-0.84	-0.85
21	0.008	-0.74	-0.84
22	0.008	-0.74	-0.74
23	0.008	-0.71	-0.74
24	0.008	-0.80	-0.62
25	0.008	-0.76	-0.80
26	0.009	-0.65	-0.76
27	0.009	-0.55	-0.66
28	0.010	-0.78	-0.79
29	0.009	-0.68	-0.73
30	0.008	-0.65	-0.69
31	0.005	-0.85	-0.66
32	0.003	-0.88	-0.77
33	0.001	-0.92	-0.84
34	0.001	-0.94	-0.87
35		-0.96	-0.89
36		>1.26	
37		>1.26	
38		>1.26	
39		>1.26	
40			

$y_{(c)}$ = water level in well $_c$.

4.4. Determination of Linear Relationship Between Predicted And Observed Values.

The relationship between predicted and observed values, are determined using tables 4.8 to 4.10. The graphical representation are shown in Figures 4.1 to 4.3 Here, predicted constantly increased throughout with the unit change in observed values. The functional form of the linear relationship between predicted values (dependent variable) and observed values (independent variable) is represented by the equation.

$$Y= \lambda + \beta x \text{ ---------------- } 4.1$$

Where λ is the intercept of the line on the predicted (Y) axis and β, the linear regression coefficient, is the slope of the line or the amount of change in Y, for each unit change in observe (X). The λ is the intercept (i.e the value of y when x is zero) and β the regression coefficient associated with the observed values, this represents the amount of change in predicted value of change in observed values. The presence of β (i.e, where the value of β is not zero) indicates the dependence of predicted on observed. In other words, if $\beta = 0$, then predicted values do not depend on observed values (i.e, there is no association between predicted values and observed values in the manner prescribed).

4.4.1 Simple Linear Regression and Correlation

For the simple linear repression to be applicable, the following conditions must hold.

i. There is only one independent variable x (observed values) the dependent variable y (predicted values).

ii. The relationship between predicated and observed values is known, or can be assumed to be linear. Although these two conditions may seem to restrictive, they are often satisfied for data from controlled experiments. Most controlled experiments are designed to keep the many factors that can simultaneously influence the dependent variable constant (such as α μ and t) and to vary only the factor (treatment) being investigated.

The regression analysis deals with the estimation and tests of significance concerning the two parameters λ and β in the equation 4.1. But this does not provide any test as to whether the best functional relationship between X and Y is indeed linear.

4.4.2 The Linear Regression Analysis With Predicted and Observed Values of Groundwater Table.

Tables 4.8 to 4.10, were used to estimate the simply linear regression between predicted and observed water table. The primary objective of the analysis is to estimate a linear response in predicted values (models) to the observed values, and to test whether this linear response is significant.

Computing the Means

$\bar{x} = \sum x/n$ ---------------- 4.2

$\bar{y} = \sum y/n$ ---------------- 4.3

Corrected sums of squares

Of x $\Sigma x^2 = \sum_{i=1}^{n} (x_i - \bar{x})^2$ -------------4.4

Of y $\Sigma y^2 = \sum_{i=1}^{n} (x_i - \overline{y_i})^2$ -------------4.5

Corrected sums of cross products

$\Sigma xy = \sum_{i=1}^{n} (x_i - \bar{x})(y_i - \bar{y})^2$ -------------4.6

Table 4.8 Estimated Simple linear Regression between Predicted and Observed Water Levels **(Well A)**

S/No.	Observed x_0(m)	Predicted (y) y_e(m)	Deviation from (mean) $(x_0-\bar{x})$ x	$(y_p-\bar{y})$ y	Square of deviation X^2	y^2	Product of deviates (x)(y)
1.	-1.37	-1.78	-1.05	-1.53	1.1025	2.3409	1.6065
2.	-1.40	-1.79	-1.08	-1.53	1.1664	2.3409	1.6524
3.	-1.40	-180	-1.08	-1.55	1.1664	2.4025	1.674
4.	-1.42	-1.91	-1.10	-1.66	1.2100	2.7556	1.826
5.	-1.51	-1.99	-1.19	-1.74	1.4161	3.0276	2.0706
6.	- 1.57	1.56	-1.25	-1.31	1.5626	1.7161	1.6275
7.	-1.62	-1.23	-1.30	-0.98	1.69	0.9604	1.274
8.	-1.39	-1.26	-1.07	-1.01	1.1449	1.0201	1.0888
9.	-1.22	-1.07	-0.90	-0.82	0.8100	0.6724	0.738
10.	-1.20	-0.94	- 0.88	-0.69	0.7744	0.4761	0.6072
11.	0.25	-9.2	0.57	-0.67	0.3249	0.4489	0.3819
12.	0.17	0.03	0.49	0.28	0.2401	0.0784	0.1372
13.	- 0.21	0.17	0.11	0.42	0.0121	0.1764	0.0462
14.	- 0.9	-0.12	-0.58	0.13	0:3364	0.0169	0.0754
15.	0.23	-0.65	0.55	0.40	0.3025	0.1600	0.2200
16.	0.25	0.26	0.57	0.51	0.3249	0.2601	0.2907
17.	0.26	0.27	0.58	0.52	0.3364	0.2704	0.3016
18,	0.25	0.27	0.57	0.52	0.3249	0.2704	0.2964
19.	0.20	0.27	0.52	0.52	0.2704	0.2704	0.2704
20.	0.26	0.23	0.58	0.48	0.3364	0.2304	0.2784
21.	0.26	0.26	0.58	0.51	0.3364	0.2601	0.2958
22.	0.26	0.26	0.58	0.51	0.3364	0.2601	0.2958
23.	0.26	0.26	0.58	0.51	0,3364	0.2601	0.2958
24.	0.26	0.26	0.58	0.51	0.3364	0.2601	0.2958
25.	0.22	0.26	0.54	0.51	0.2916	0.2601	0.2754
26.	0.26	0.23	0.58	0.52	0.3364	0.2304	0.2784
27.	0.27	0.27	0.59	0.52	0.3481	0. 2704	0.3068
28.	0.26	0.27	0.58	0.52	0.3364	0. 2704	0.3016
29.	0.22	0.27	0.54	0.52	0.2916	0.2704	0.2808
30.	0.21	0.23	0.53	0.43	0.2809	0.1849	0.2273
31.	0.14	0.22	0.46	0.47	0.2116	0.2209	0.2162
32.	0.03	0.14	0.35	0.39	0,1225	0.1521	0.1365
33.	0.26	0.024	0.58	0.274	0.3364	0.0751	0.15892
34.	0.26	0.21	0.58	0.46	0. 3364	0. 2116	0. 2668
35.	0.19	0.21	0.51	0.46	0.2601	0.2116	0.2346
36.	- 0.12	0.15	0.20	0.40	0.0400	0.1600	0.0800
37.	- 0.63	- 0.01	- 0.31	0.24	0.0961	0.0576	0.0744
38.	- 0.83	- 0.50	- 0.51	- 0.25	0.2601	0.0625	0.1275
39.	- 0.94	- 0.66 - 0.74	- 0.62	- 0.42	0.3844	0.1764	0.2604
Mean	- 0.32	- 0.25	- 0.02	- 0.09	0.52	0.609	0.504
Sum	- 12.5	- 10.08	- 0.65	- 3.47	20.43	23.75	19.67

Negative sign = Depth of water below the ground surface

Table 4.9: Estimated Simple linear Regression between Predicted and Observed Water Levels **(Well B)**

S/No.	Observed x_0(m)	Predicted (y) y_c(m)	Deviation from (mean)		Square of deviation		Product of deviates (x)(y)
			($x_0-\bar{x}$) x	($y_p-\bar{y}$) y	X^2	y^2	
1.	-2.52	-2.85	-1.08	-1.09	1.1664	2.1881	1.1772
2.	-2.55	-2.86	-1.11	-1.100	1.2321	2.2400	1.221
3.	-2.56	-2.87	-1.12	-1.11	1.2544	1.2321	1.2432
4.	-2.57	2.90	-1.13	-1.14	1.2769	1.2996	1.2882
5.	-2.60	3.21	-1.16	-1.45	1.3456	2.1025	1.682
6.	<-2.69	- 2.88	- -	-1.12	- -	1.2544	- -
7.	< -2.69	-2.85	- -	- 1.09	- -	0.1881	- -
8.	- 2.55	-2.73	-1.11	- 0.97	1.2321	1.4409	1.0767
9.	- 2.45	-2.44	-0.01	- 0.68	0. 0204	0.4624	0.688
10.	- 2.40	-2.35	- 0.96	- 0.59	0.9216	0.3481	0.5664
11.	-1.76	-2.31	- 0.32	- 0.55	0. 1074	0.3025	0.176
12.	- 2.43	-1.78	- 0.99	- 0.02	0.9801	0.0004	0.0198
13.	- 2.46	- 2.41	- 1.02	- 0.65	1.0404	0.4225	0.663
14.	- 2.40	- 2.47	-0.96	- 0.71	0.9216	0.5041	0.6816
15.	- 2.56	- 2.57	- 1.12	- 0.81	1.2544	0.6561	0.9072
16.	- 2.255	- 2.71	- 1.11	- 0.95	1.2321	0.9025	1.0545
17.	- 1.50	- 2.70	- 0.06	- 0.94	0.0036	0.8836	0.0564
18,	- 1.01	- 1.72	0.43	0.04	0.1849	0.0016	0.0172
19.	- 1.02	- 1.28	0.42	0.48	0.1764	0.2304	0.2016
20.	- 0.98	- 1.29	0.46	0.47	0.2116	0.2209	0.2162
21.	- 0.95	- 1.19	0. 49	0.57	0.2404	0.3249	0.2793
22.	- 0.92	- 1-15	0. 52	0.61	0.2704	0.3721	0.3172
23.	- 0.52	- 1.12	0. 92	0.64	0.8464	0.4096	0. 5888
24.	-0.71	-0.00	0. 73	0.74	0.5329	0.0276	0.2702
25.	- 0.60	- 0.94	0. 84	0.82	0.7056	0.6724	0.6888
26.	- 0.54	- 0.84	0. 90	0.92	0. 8100	0.8464	0.828
27.	-0.40	-0.82	1.04	0.94	1.0816	0. 8836	0.9776
28.	- 0.50	- 0.69	0.94	1.07	0.8836	1.1449	1.0058
29.	- 0.51	- 0.82	0.93	0.94	0.8649	0. 8836	0.8742
30.	- 0.62	- 0.38	0.82	1.38	0.6724	0.9044	1.1316
31.	- 0.67	- 0.85	0.77	0.91	0.5929	0.8281	0.7007
32.	- 0.66	- 0.79	0.78	0.97	0.6884	0.9409	0.7566
33.	- 1.55	- 0.71	- 0.11	1.02	0.0121	1.0404	0.1122
34.	- 0.71	-1.43	0.73	0.33	0.5329	0.1089	0.2409
35.	- 1.11	- 0.68	0.33	1.08	0.1089	0.1664	0.3564
36.	- 2.00						
37.	- 2.00						
38.	<- 2.69						
39.	<- 2.69						
Mean	- 1.44	- 1.76	- 0.07	- 0.001	0.74	0.85	0.69
Sum	- 50.24	- 61.61	- 2.32	- 0.04	24.40	29.0025	22.84

Table 4.10: Estimated Simple linear Regression between Predicted and Observed Water Levels **(Well C)**

S/No.	Observed x_0(m)	Predicted y_p(m)	Deviation from (mean) $(x_0-\overline{x})$ x	$(y_p-\overline{y})$ y	Square of deviation X^2	y^2	Product of deviates (x)(y)
1.	<-1.69						
2.	<-1.69						
3.	<-1.69						
4.	<-1.69						
5.	<-1.69						
6.	<-1.69						
7.	<-1.69						
8.	-1.25		- 0.33		0.1089		
9.	-1.23	-1.20	-0.31	- 0.29	0.0961	0.08541	0.0899
10.	-1.21	-1.20	- 0.29	- 0.29	0.0841	0.0841	0.0841
11.	- 1.18	-1.16	- 0.26	- 0.25	0.0676	0.625	0.065
12.	- 0.82	- 1.14	0.10	- 0.23	0.01	0.0529	0.023
13.	- 0.89	- 0.81	0.03	- 0.10	0. 0009	0.10	0.003
14.	-1.20	-0.88	- 0.28	- 0.03	0.0784	0.0009	0.0084
15.	- 1.18	- 1.18	-0.26	- 0.27	0.0676	0.0729	0.0702
16.	- 1.17	- 1.17	- 0. 25	- 0.26	0.0625	0.0676	0.065
17.	- 1.19	- 1.16	- 0.27	- 0.25	0.729	0.0625	0.0675
18,	- 1.21	- 1. 81	- 0.29	- 0.26	0.0841	0.0676	0.0754
19.	- 0.84	- 1.20	0. 08	- 0.29	0.0064	0.0841	0.0232
20.	- 0.84	- 0.85	0. 08	0.06	0.0064	0.0036	0.0048
21.	- 0.74	- 0.84	0. 18	0.07	0.0324	0.0049	0.0126
22.	- 0.74	- 0.74	0.21	0.17	0.0324	0.0289	0.0306
23.	- 0.71	- 0.74	0.21	0.17	0.0441	0.0289	0.357
24.	- 0.80	- 0.62	0.12	0.29	0.0144	0.0841	0.0348
25.	- 0.76	- 0.80	0.16	0.11	0.0256	0.0121	0. 0176
26.	- 0.65	- 0.76	-0.27	0.15	0.0729	0.0225	0.0405
27.	- 0.55	-0.66	0.37	0.25	0.1369	0.0625	0.0925
28.	- 0.78	- 0.79	0.14	0.12	0.0196	0.0144	0.0168
29.	- 0.68	- 0.73	0.24	0.18	0.0576	0.0324	0.0432
30.	- 0.65	- 0.69	0.27	0.22	0.0729	0.0484	1.0594
31.	- 0.85	- 0.66	0.07	0.25	1.0049	0.0625	0.0175
32.	- 0.88	- 0.77	0.04	0.14	0.0016	0.0196	1.00566
33.	- 0.92	- 0.84	0.00	1.07	0.00	0.0049	0.00
34.	- 0.94	- 0.87	0.02	0.04	0.0004	0.0016	0.0008
35.	- 0.96	- 0.89	0.04	0.02	0.0016	0.0004	0.0008
36.	<- 1.26						
37.	<- 1.26						
38.	<- 1.26						
39.	<- 1.26						
Mean	- 0.92	- 0.91	- 0.002	- 0.002	0.045	0.04	0.032
Sum	- 25.82	- 24.53	- 0.06	- 0.05	1.2632	1.08	0.8755

Computing the estimates of the regression parameters λ and β for well A as:-

$a = \bar{y} - b\bar{x}$ -------------------------------- 4.7

$b = \sum xy / \sum x^2$ -------------------------------- 4.8

For our calculation, the estimates of the two regression parameters a and b using equations 4.7 and 4.8 are as follow:-

Well A

$\beta = 19.67/20.45 = \underline{\underline{0.96}}$ Regression coefficient

$\lambda = -0.25 - (0.96)(-0.32) = 0.0572$ intercept

Thus, the estimated linear regression is

$\hat{y} = a + bx$

$\hat{y} = 0.057 + 1.92x$ for $-151 \leq x \; 0.27$

Well B

Regression coefficient = b

$B = 22.84/24.40 = \underline{\underline{0.94}}$

Intercept $a = -1.76 - 0.44(-1.44)$

$= -0.41$

Thus, the estimated linear regression is

$\hat{y} = -0.41 + 0.94x$ $-2.56 \leq x \leq -0.40$

Well C

$B = 0.8755/1.2632 = 0.69$

$q = -0.91 - (0.6x - 0.92) = -0.28$

Thus the estimated linear regression is

$\hat{y} = -0.28 + 0.69x \qquad -1.23 \leq x \leq -0.55$

4.4.3 Validation of Models

Testing the significance of β: by computing the residual mean square as:

$$S^2_{yx} = \frac{\sum y^2 - (\sum xy)^2/\sum y^2}{n-2} \quad \text{------------------------------} \; 4.9$$

$$t_b = b/\sqrt{(S^2yx/\sum x2)} \quad \text{------------------------------} \; 4.10$$

WELL A

The residual mean square the t_b values are computed as:-

$$23.75 - \underline{(19.64)^2} = 4{,}812/37 = 0.13$$

$$t_b = 0.96/\sqrt{0.18/20.43} = 0.96/0.08 = 12.02$$

WELL B

$$S^2_{yx} = \frac{29.0025 - (22.84)^2/24.40}{33} = 0.231$$

$$t_b = 0.94/\sqrt{0.231/24.42} = 9.66$$

WELL C

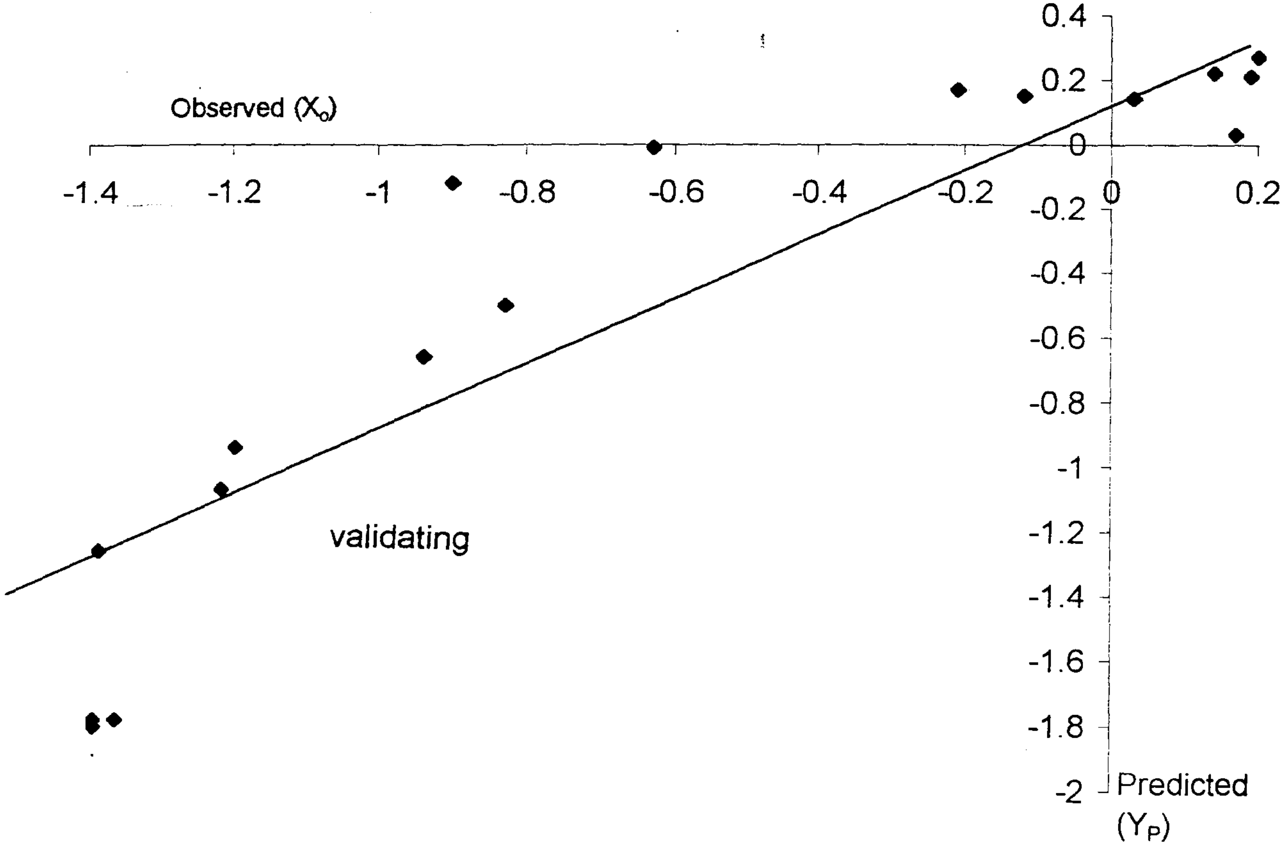
$$S^2_{yx} = 1.08 - (0.8755)^2/1.2632/25 = 0.019$$

$$t_b = +\,0.69/\sqrt{0.019/1.2632} = 5.64$$

The absolute values of the computed t_b value are greater than the tabular t value at the prescribed level of significance. Because the computed t_b value is greater than the tabular value at the 5% and 1% level of significance, the linear response of predicted ground water level to change in observed groundwater level is significant outside 5% and 1% level of significant

The correlation coefficient is the correlation analysis a statistical method which measures the degree of association between predicted and observed water tables. The significance of the correlation coefficient could not be determined from table which related values of the coefficient to different levels of significance. This is because the absolute value, the calculated correlation coefficient exceeded the significance represents the probability of having drawn the wrong conclusion.

Simple linear regression, was also conducted in the sample data to achieve the same goal as graphical regression analysis, that is simply drawing straight line (Fig. 4.1-4.3) through the data by eye and deciding by inspection whether or not the relationship is significant. This is done by computing gradient.



The Slope = $Y_{max} - Y_{min}/(X_{max} - X_{min})$

$$= \frac{-0.22 + 1.1}{-0.1 + 0.8}$$

$(X_0 : Y_p)$ (1:1.23) = **1.23**
any unit change in X_0
cause a change of
1.23 in predicted values

Validating by substituting the value of x at min and max
$Y = 0.08 + 1.23x$
When X is at (0.27)

$Y = 0.08 + (1.23)(0.27)$
$= -0.08 + 0.3321$
$= 0.25$
by checking $Y = 0.27$ $Y = 0.25$
with difference of 0.0179

Figure 4.1: The Estimated Linear Regression between Predicted (Y_p) and Observed (X_0) Values of Ground water Table (Well A)

The slope = $\frac{+0.4 - 3.2}{+0.16 - 7.6} = 1.15$

$(X_0\ Y_p)$ (1 : 1.15)
any unit change in X_0 cause a change of 1.15 in predicted values

$Y = -0.42 + 1.15X$
by validating when X at max
$Y = -0.42 + (1.15)(-2.60)$
$Y = -3.41$

Comparing Y and Y_{pmax}

$Y = -3.4$ $\quad Yp = 3.21$
with difference of 0.19

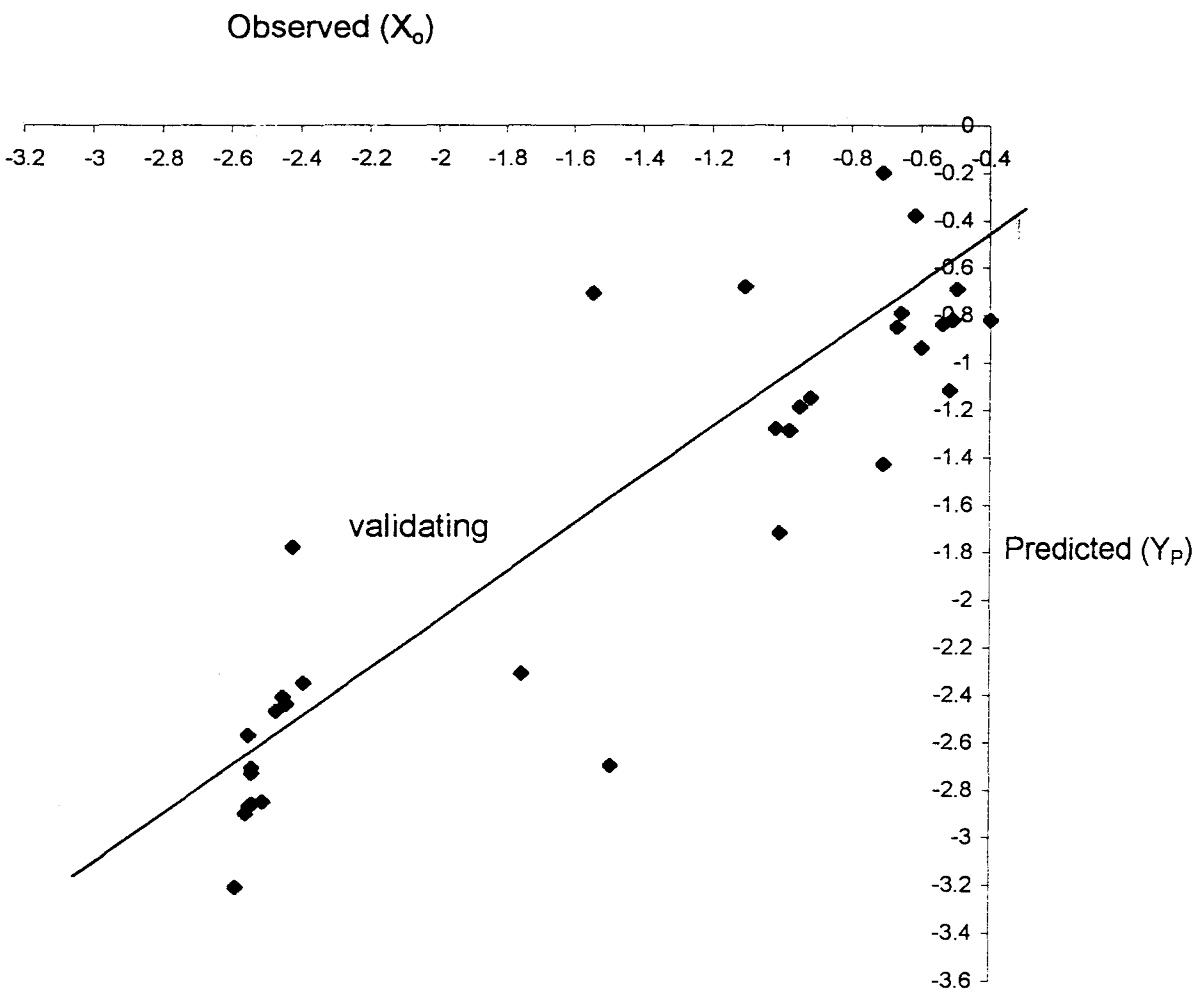


Figure 4.2: The Estimated Linear Regression between Predicted (Y_p) and Observed (X_0) Values of Ground water Table (Well B)

The slope = $\frac{-0.6 + 1.4}{-0.5} = 0.8$

(X_0 : Y_p) (1: 0.8)

any unit change in X_0 cause a change of 0:8 in predicted values.

:- $Y = -0.19 + 0.8X$

by validating when X is min -1.23

$Y = -0.19 + (0.8)(-1.23)$
$= -1.174$

Compearing Ymax and Ypmax

1.20 - 1.174 = 0.026
with the difference of
0.026

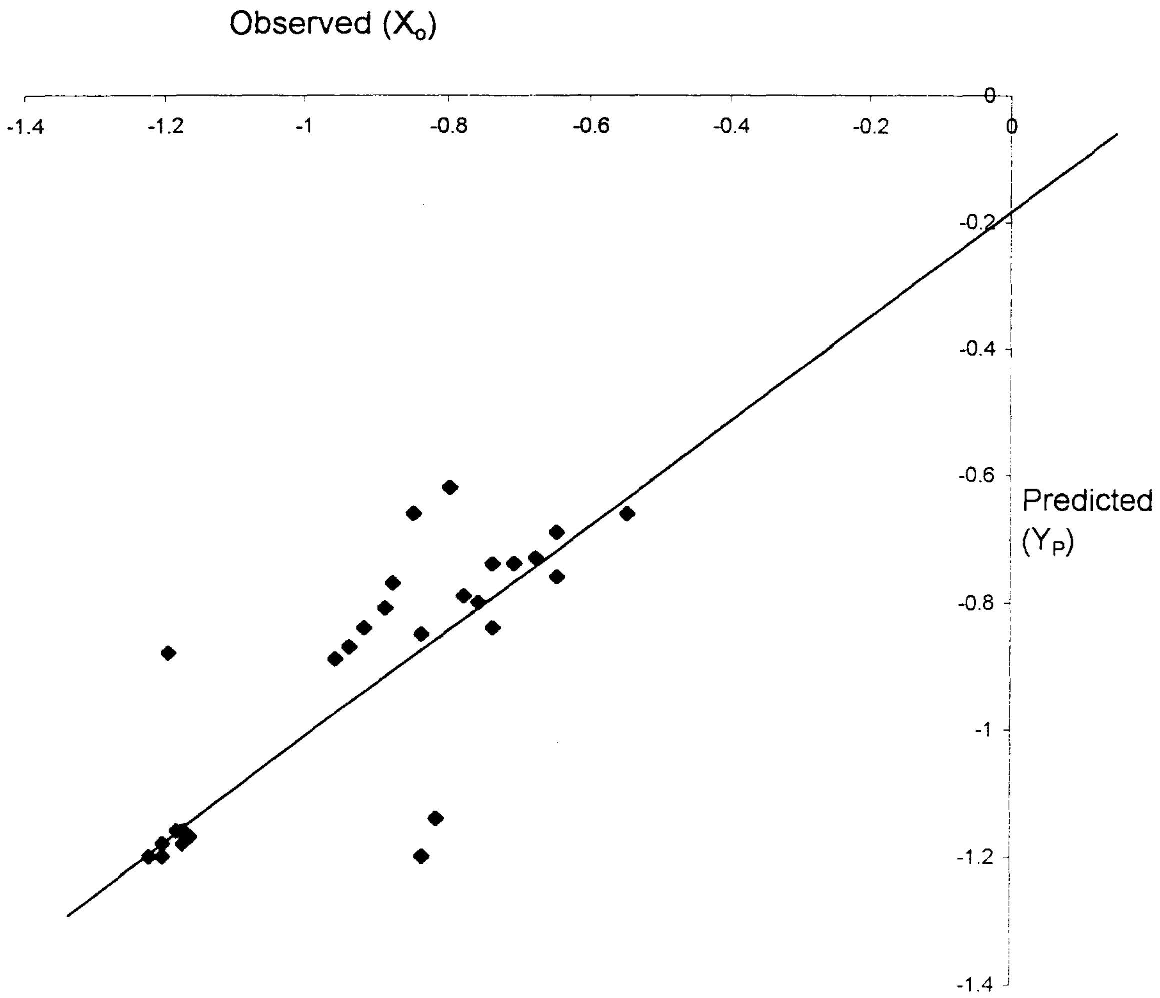
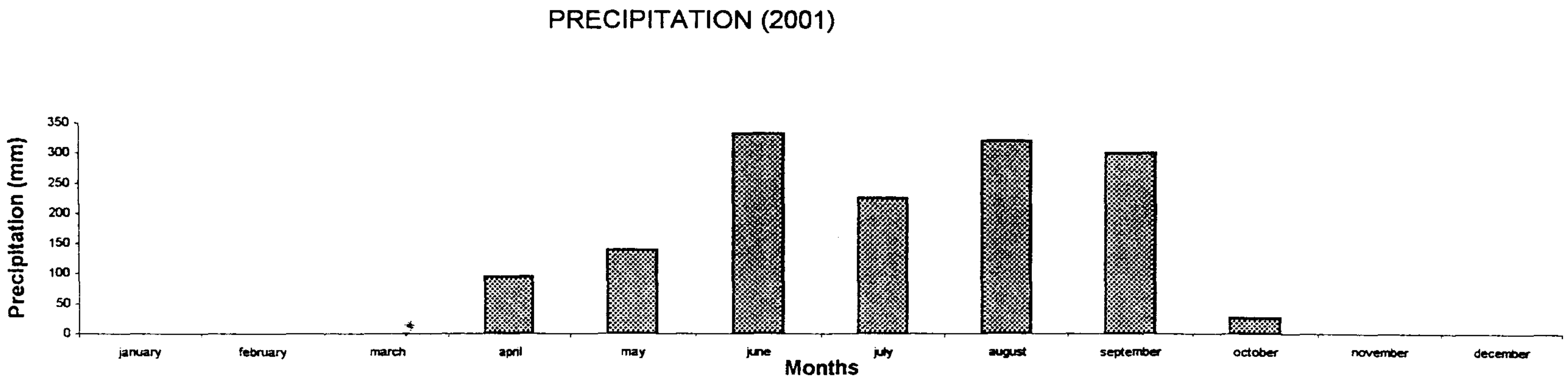


Figure 4.3: The Estimated Linear Regression between Predicted (Y_p) and Observed (X_0) Values of Ground water Table (Well C)



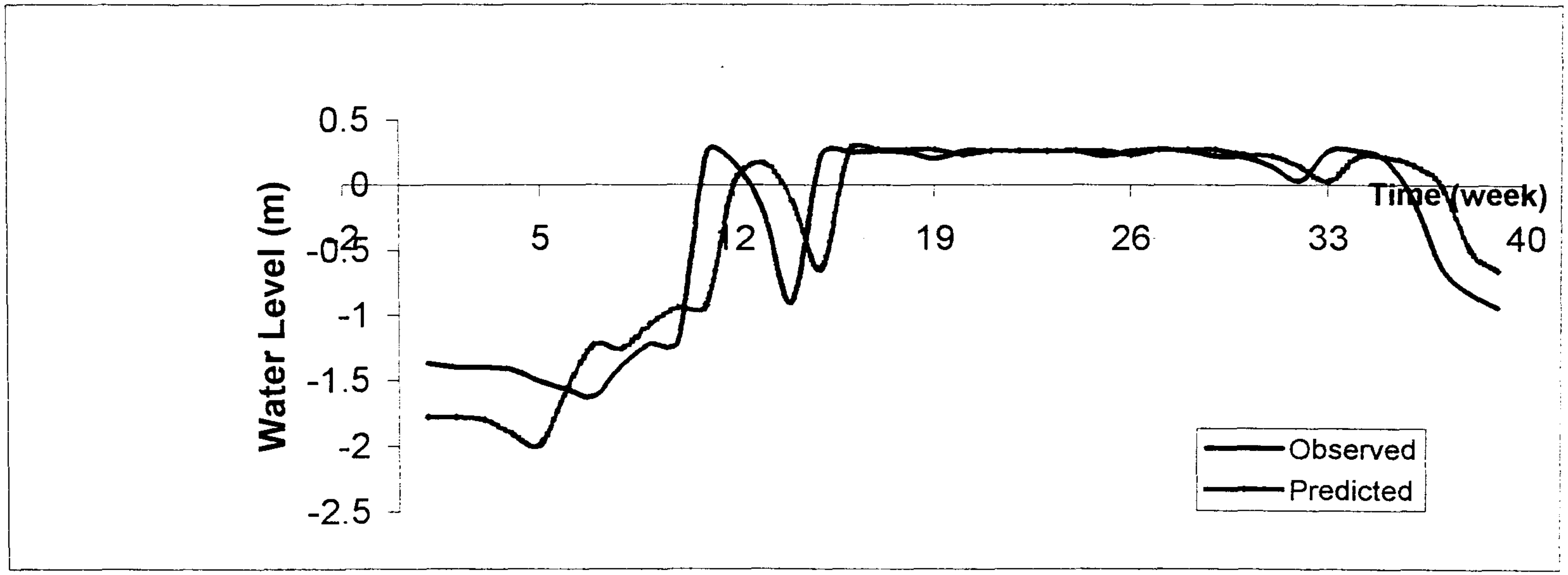


Figure 4.4: Observed Ground Water Table versus Predicted (WellA)

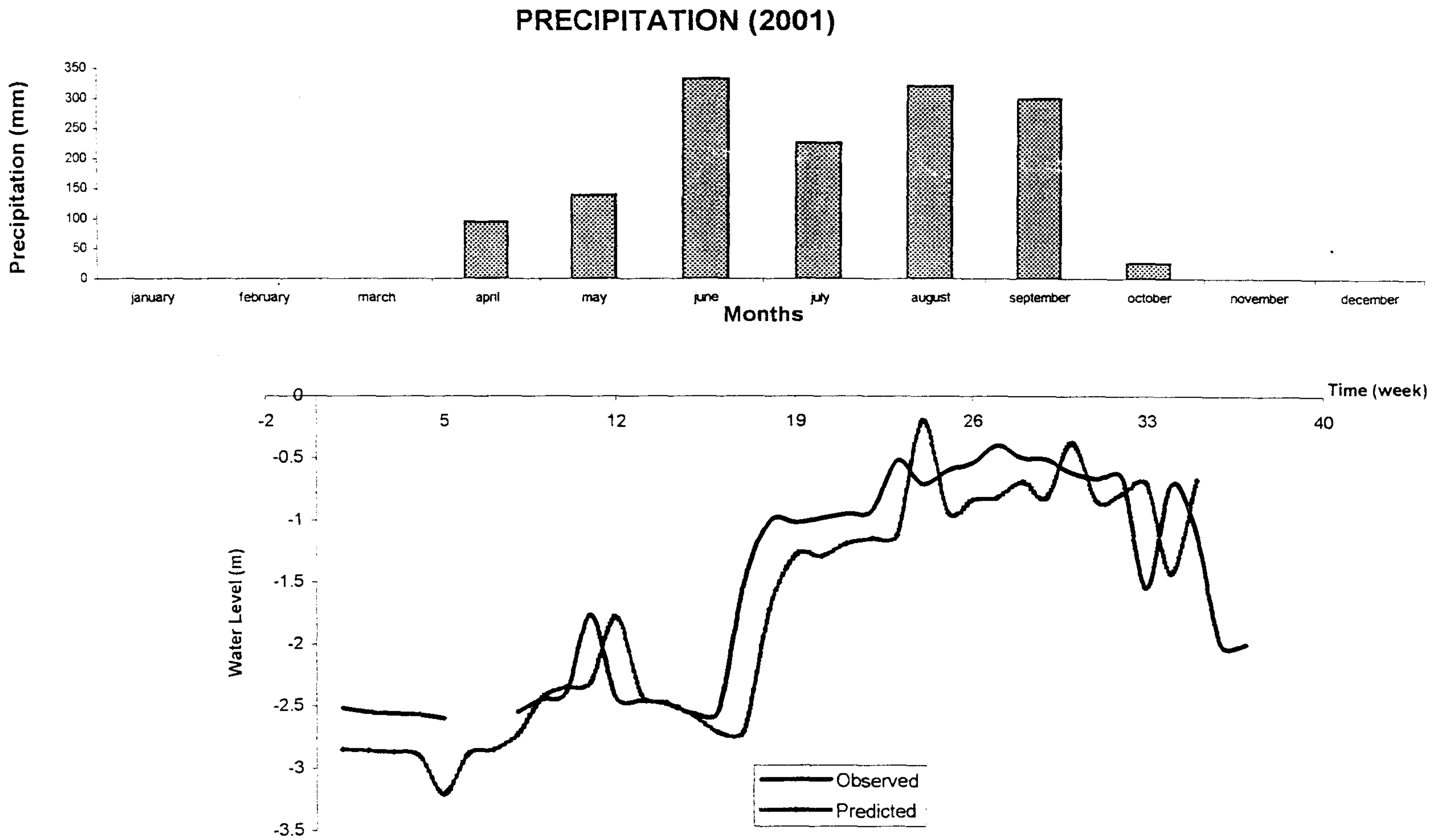
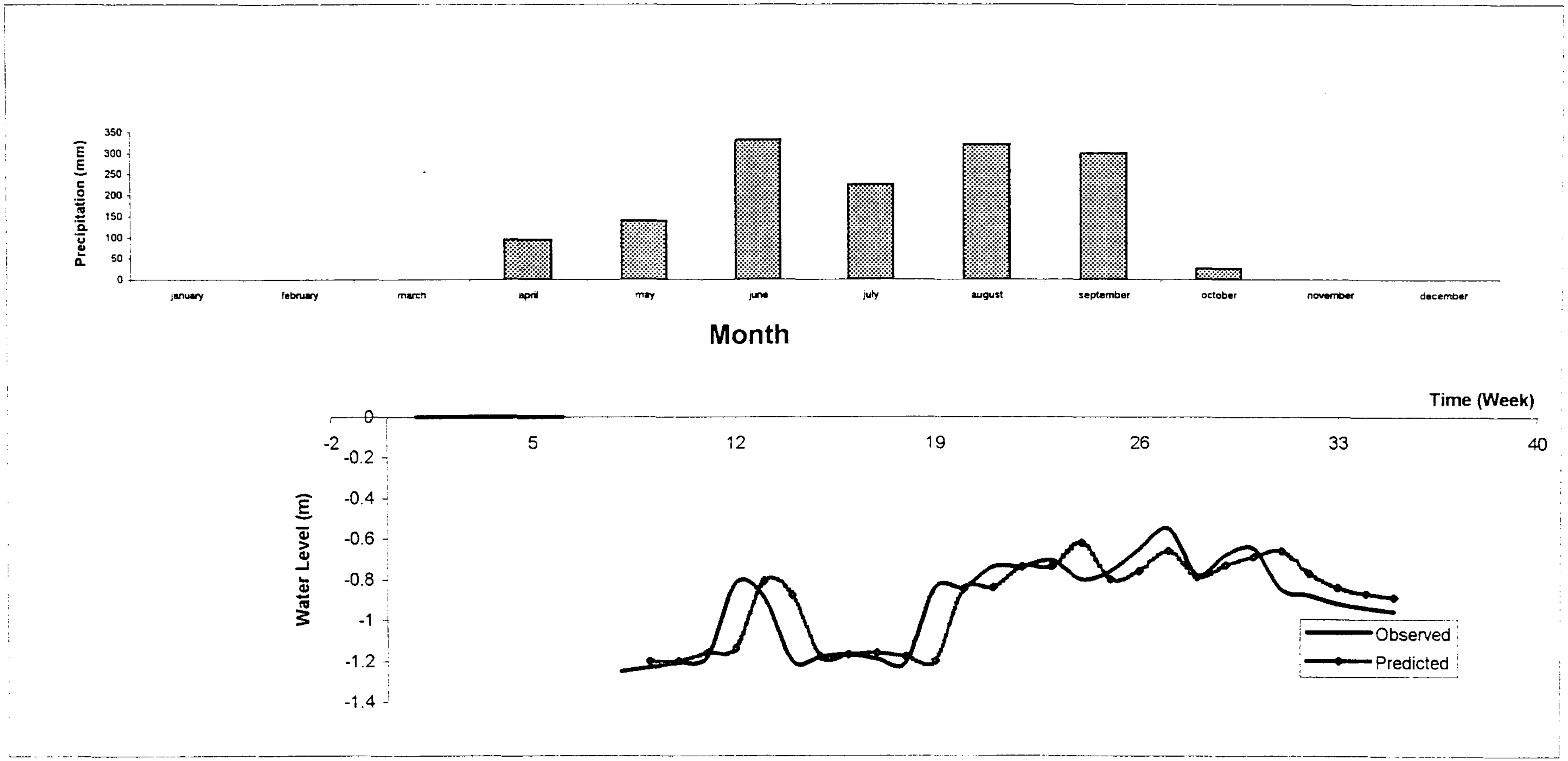


Figure 4.5: Observed Ground Water Table versus Predicted (WellB)



PRECIPITATION (2001)

Figure4.6: Observed Ground Water Table versus Predicted. (Well C)

And also the value of correlation coefficient lies within the range of −1 and +1, with the extreme value indicating linear association and the midvalue of zero indicating no linear association between the two predicted and observed values of water table

Compute the simple linear correlation coefficient as

٢ = $\Sigma xy/\sqrt{((\Sigma x^2)\ (\Sigma y^2))}$ ---------------------- 4.11

For **Well A** from Table 4.9

٢ = $19.67/\sqrt{((20.43)\ (23.75))} = 0.89$

٢ = (100)٢^2 = $100 \times (0.89)^2 = 79.74\%$

Well B

٢ = $22.84/\sqrt{(24.40)}\ (29.0025) = 0.86$

٢ = (100)٢^2 = $100 \times (0.86)^2 = 73.72\%$

Well C

٢ = $0.8755/\sqrt{((1.2632)\ (1.08))} = 0.75$

٢ = 100٢^2 = $100\ (0.75)^2 = 56.18\%$

The computed values of ٢ are 0.89 for well A, 0.86 for well B and 0.75 for Well C. Comparing the absolute value of the computed ٢ to the tabular ٢ values with (n – 2) = 37,33 and 26 for well A, well B and well C as levels of freedom, which are found in text, with the 5% and 1% levels of significance it was confirmed that all the ٢ values for wells A, well B and well C are significant. This is because the computed ٢ values are grater than the tabular ٢ value at 5% level and as well at ٢ value at the 1% level. Their values were judged in relation to the sample size n which also exceeded tabular ones.

Therefore, 79.76%, 73.72% and 56.18% of the observed values of water table accounted for the linear function of modells development in well A, well B and well C respectively. Moreover, r values within the range of -1 and +1 indicating linear association rather than zero.

4.5 Causes of Fluctuation of the Watertable in the Project Area

However, refractor velocity V_2 contour map on Geological formation (Fig. 4.7) revealed that the depth of well B and well C ended on more consolidated formation while that of well A is located on low rock consolidation. Whenever, there is rain fall water hardly infiltrate into the soil to recharge the wells, but well (A) is found in depression in a water logged area, where rainwater can gradually infiltrate into the soil to recharge the well.

Well (B) and well (C) have slopes that enable rainwater to flow into an existing stream as runoff. And when the two wells (B and C) are finally recharged they discharge into the nearby stream through the available pore spaces.

In view of fig.4.7, with respect to refractor velocities, it shows that, the region of aquifer having higher velocities is highly consolidated and compacted, that must have resulted to little or no pore spaces in the medium. However, a-region with low refractor velocities has medium in such area to be less consolidated, having appreciable pore spaces. The flow of water in the soil depends mainly on available pore spaces through which it flows i.e. there is interconnectivity of pore spaces between the medium (aquifer). Therefore recharge, underground water flow will be high in the area of low refractor velocity. This explains why there is always water in well (A) that is found in rock with low refractor velocity. If material is said to be compacted it means that its pore space is limited or eliminated and its density increased. So, it must have higher refractor velocity and no longer permeable, like rock found in the locations of well B and Well C. The low V_2 signifies the easy with which, water can recharge aquifer in such an area.

4.6 **Limitation of the Models**

The model are effective only when R> O, if the groundwater body is recharged by rainfall or by another sources (R) and is depleted by drain discharge (q), it fellows that the water table will rise when $(R-q) > 0$ and fall when $(R-q) < 0$. But when $R = 0$ for long period of time and at the same time of interval, the models derived tends to bring the water level from below and above to the ground surface, (i.e $\pm y \Rightarrow 0$)

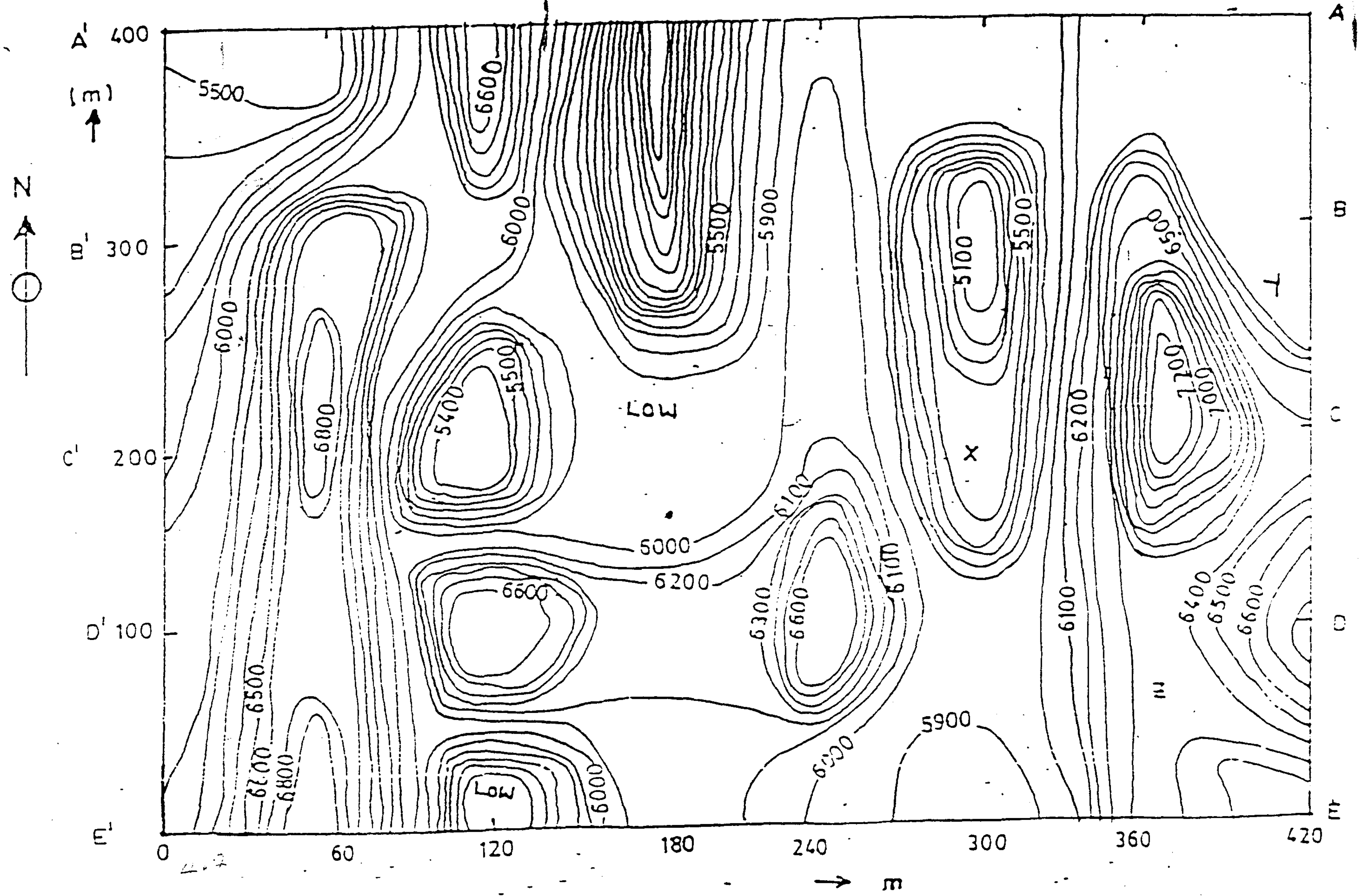


Fig 3.7 · Refractor Velocity, V_2 (m/s) Contour Map On Geological Formation ([illegible]) Interval of 100 m/s

Source:- (Adeniyi, 2001).

CHAPTER FIVE

SUMMARY CONCLUSION AND RECOMMENDATIONS

5.1 **Summary**

An investigation was carried to determine the ground watertable fluctuation trend in Gidan Kwano about 15km South of Minna at the Federal University of Technology (farm) Permanent Site. The data collection covered a period of 9 months, from March to November. The range of ground water table fluctuation is from 1.62m below the ground surface in March to 0.27m above the ground surface in the month of September (well A). Major operation carried out on the field included: well boring, construction of piezometric pipes, installation of piezometric pipes and measurement of ground water level.

Equation 3.14 was used to form models for wells A, B and C after the determination of reaction factors for each well ($\propto_a = 0.24$, $\propto_b = 0.11$ and $\propto_c = 0.064$) and pore spaces ($\mu_a = -16\%$, $\mu_b = 3\%$ and $\mu_c = 20\%$).

Analysis was carried out on the models using difference method such as:-

a. simple linear a regression method that gives the values of regression coefficient as $b_A = 0.96$,b_B 0.94 and $b_C = 0.69$ which is clear indication of predicted model depends on observed values. The relatively high of corrolation coefficient (μ) values obtained are; $\mu_A = 0.89$, $\mu_B = 0.86$ and $\mu_C = 0.75$ also indicate the closeness between the estimated predicted line and the observed points.

5.2 **Conclusion**

The farm area has significant potential for development of ground water for irrigation scheme most especially, in the area of low refractor velocity where the field is located. It indicates that region of xyz is more consolidated than any other part in this mapped area, which cannot sustain well. Groundwater is expected along the well developed fractures which trend NNW-SSE and NNE –SSW, (location of well (A)). Thus the suitability of low refractor velocity region for sitting well is confirmed. Cluster of shining spots called mottling were observed from the drilled soil in this area, which means that, it is always water logged.

The reaction factor is a direct index of the intensity with which the discharge rate responds to changes in the recharge values from well A, well B and well C are 0.24,0.11 and 0.064 respectively. These are low response; it shows that their KD are low with high drainable pore space into the stream. Well A has high value of 0.24, which is still within the range of slow response. On the drainable pore space, well C has the highest % of 20% followed by well B with 3% and well A with least value of -16%, signifies opposing drainage.

The simple linear regression analysis that gives the values of b_A for Well A = 0.96, b_B for Well B = 0.94 and b_C for Well C = 0.69 is clear indication that dependence of predicted on observed groundwater table. The relatively high ٢ value obtained as: Well A = 0.89, Well B = 0.86 and Well C 0.75 is also indication of the closeness between the estimated regression line and the observed points.

Groundwater level fluctuation models have been developed which are:-

(i) $h_t = h_{t-1}e^{-0.24^{\delta}t} + R_{\delta t} / 0.031 (1 - e^{-0.24^{\delta}t})_{\text{well}}$ (A)

(ii) $h_t = h_{t-1}e^{-0.11^{\delta}t} - R_{\delta t} / 0.0027 (1 - e^{-0.11^{\delta}t})_{\text{well}}$ (B)

(iii) $h_t = h_{t-1}e^{-0.064^{\delta}t} - R_{\delta t} /0.0104 (1 - e^{-0.064^{\delta}t})_{\text{well}}$ (C)

5.3 **Recommendations**

1. There should be enough data for the model development of based on daily rainfall and ground water table fluctuation throughout the years (10) then, the model will be of better of fitt.
2. A typical map should be prepared showing the variation of the coefficients of storage and tranmmisivity in the study area. These factors partly determine the ease with which groundwater table can fluctuate.
3. There were so many questionable values in the data collected e.g rainfall of June 2001 value obtained for that month was extremely high, that could be one of the factor leading to the models to be out of range of 5% and 1% levels.
4. The absolute values of the calculated correlation coefficient exceeded the tabular values, the correlation exists and level of significance represents the probability of having drawn the wrong conclusion of the time internal used for the data collection estimated pore space obtained, reaction factor used and applied water (R). These explains why the level of significance are out of range of 5% and 1% levels.

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APPENDICES

Appendix A: Physico-Chemical Properties of Soil Samples of Gidan-Kwano.

Soil properties	Gidan-Kwano	
Soil Depth, cm	0 – 20	20 – 40
pH (1:2.5) in water	6.80	6.87
pH (1:2.5) in 0.01m $CaCl_2$	6.44	6.38
Bulk Density, gcm^3	1.72	1.68
Sand, %	75.52	58.2
Silt, %	6.78	6.78
Clay, %	17.70	25.20
Textural Class, gkg^{-1}	sandy loam	sandy clay loam
Organic Carbon, gkg^{-1}	1.77	0.90
Organic matter gkg^{-1}	3.05	1.55
Total N,gkg^{-1}	0.08	0.12
Available P, $mgkg^{-1}$	7.53	7.53
Exchangeable Na^+, $cmolskg^{-1}$ soil	0.54	0.53
Exchangeable K^+, $cmolskg^{-1}$ soil	0.14	0.17
Exchangeable Ca^{2+}, $cmolskg^{-1}$ siol	3.44	2.08
Exchangeable Mg^{2+}, $cmolskg^{-1}$ siol	1.88	5.08
Exchangeable Acidity($H^+ + Al^{3+}$) $cmolskg^{-1}$ soil		
C. E. C., $cmolskg^{-1}$ soil	1.60	1.29
Base Saturation, %	7.60	9.06
	78.95	86.75

Source : (Eze, 2000)

Appendix B: Bulk Density, gcm^{-3} cultivated and follow soils at Gidan-Kwano

Gidan-kwano site.					
Land use	B/F cult	4 EAC	8 WAC	12 WAC	Mean
Cultivated	1.64	1.54	1.76	1.60	1.61^a
Fallow	1.66	1.54	1.75	1.67	1.65^a
Mean	1.65^b	1.54^a	1.71^b	1.63^b	

Land-use x weeks interaction ($P>0.05$) = NS Source : (Eze, 2000)

Appendix C: Total porosity, % of cultivated and fallow soils at Gidan-kwano.

Gidan-kwano site.					
Land use	B/F cult	4 EAC	8 WAC	12 WAC	Mean
Cultivated	37.24	41.74	40.04	40.97	39.99^a
Fallow	35.08	42.62	34.75	37.03	37.37^a
Mean	36.16^a	42.18^b	35.39^a	39.00^{ab}	

Land-use x weeks interaction ($p>0.05$) = NS Source: (Eze, 2000)

Note: data on the same row or column carrying the same superscript differ insignificantly from other ($P>0.05$);

WAC= weeks after cultivation; B/f Cult = before cultivation.

Appendix D: Macro porosity, % of cultivation and follow soils at Gidan-kwano

Gidan-kwano site.					
Land use	B/F cult	4 EAC	8 WAC	12 WAC	Mean
Cultivated	2.57	9.05	7.11	5.34	6.01^a
Fallow	2.78	8.16	5.83	6.37	5.80^a
Mean	2.77^a	8.60^c	6.47^b	5.81^b	

Land-use x week interaction ($P>0.05$)= NS Source: (Eze, 2000)

Appendix E: Micro porosity, % of cultivation and follow soils at Gidan-kwano

Gidan-kwano site.					
Land use	B/F cult	4 EAC	8 WAC	12 WAC	Mean
Cultivated	34.67	32.69	32.93	35.63	33.98^{b}
Fallow	32.21	34.46	28.92	30.66	31.56^{a}
Mean	33.44^{a}	33.57^{b}	30.92^{a}	33.14^{a}	

Land-use x week interaction (P>0.05)= NS Source: (Eze, 2000)

Note: data on the same row or column carrying the same superscript differ insignificantly from other (P>0.05);

WAC= weeks after cultivation; B/f Cult = before cultivation.

Appendix F: Volumetric water content, % cultivation and follow soils at Gidan-kwano

Gidan-kwano site.					
Land use	B/F cult	4 EAC	8 WAC	12 WAC	Mean
Cultivated	27.12	14.42	25.32	18.54	21.35^{a}
Fallow	24.05	14.96	28.16	21.63	22.20^{a}
Mean	25.58^{c}	14.69^{a}	26.74^{c}	20.08^{b}	

Land-use x week interaction (P>0.05)= NS Source: (Eze, 2000)

Appendix G: Infiltration rate of cult and fallow soils at Gidan-kwano

Gidan-kwano site.					
Land use	B/F cult	4 EAC	8 WAC	12 WAC	Mean
Cultivated	5.47	9.16	7.75	8.80	7.79^{a}
Fallow	10.81	13.75	36.70	18.98	20.06^{b}
Mean	8.14^{a}	11.45^{ab}	22.22^{b}	13.89^{ab}	

Land-use x week interaction (P>0.05)= NS Source: (Eze, 2000)

Note: data on the same row or column carrying the same superscript differ insignificantly from other (P>0.05);

WAC= weeks after cultivation; B/f Cult = before cultivation.

Appendix H: Physico-Chemical Properties of Soil from profile pit in Gidan-Kwano site.

arameters Soil properties	Gidan-Kwano site			
oil profile Depth, cm	0 – 10	15-22	22-43	43-55
h (1:2.5) in water	6.70	6.55	6.19	6.30
H (1:2.5) in 0.01m $CaCl_2$	5.37	5.23	5.38	5.60
ulk Density, gcm^{-3}	1.80	1.77	1.80	1.85
article density	2.60	2.62	2.64	265
and, %	82.04	81.04	69.04	70.04
ilt, %	8.28	8.28	10.28	9.28
lay, %	9.68	10.68	20.68	20.68
extural Class, gkg^{-1}	Loamy Sandy	Sandy loam	Sandy clay loam	Sandy clay loam
rganic Carbon, gkg^{-1}	14.60	15.00	14.6	12.7
rganic matter gkg^{-1}	25.2	25.9	25.2	22.0
otal N,gkg^{-1}	0.3	0.4	0.4	0.4
vailable Phosphorous, gkg^{-1}	4.90	7.00	5.60	6.30
xchangeable Na^+, cmolskg^{-1} oil	1.01	0.79	0.74	1.18
xchangeable K^+, cmolskg^{-1} oil	0.12	0.08	0.06	0.26
xchangeable Ca^{2+}, cmolskg^{-} siol	3.84	2.24	2.40	2.08
xchangeable Mg^{2+}, cmolskg^{-} siol	2.56	1.84	5.20	8.08
xchangeable Acidity(H^+ +	1.20	1.20	1.60	1.60
l^{3+}) cmolskg^{-1} soil	8.73	6.15	10.00	13.20
. E. C., cmolskg soil	86.25	80.48	84.00	87.87
ase Saturation, %				

Source: (Eze, 2000)

Appendix I: Laboratory Test on Water Samples

Sample No	Na	**K**	**Ca**	Mg	$Fe^{2=}$ Fe^{3+}	**Zn**	**Cl**	No_3	Hard-ness (HC03)	**SiO_2**	**pH**	**TDS**	**SAR**	Conductivity
1	40.0	2.9	0.85	Trace	Nil	Nil	18.0	0.02	101.0	0.2	6.5	276.0	16.9	$2.2x10^3$
2	22.1	6.5	1.0	1.0	Nil	Nil	17.5	0.15	135.2	0.1	6.9	247.5	5.3	$4.1x10^3$
3	28.5	4.2	0.85	Nil	Nil	Nil	10.5	Nil	151.0	0.4	6.7	224.1	12.0	$2.8x10^3$
4	45.9	4.7	1.5	Nil	Nil	Nil	15.0	0.18	125.0	0.15	6.9	390.0	14.6	$0.5x10^2$
5	17.7	2.5	0.85	Nil	Nil	Nil	6.0	Trace	64.0	0.4	6.95	242.0	7.5	$1.3x10^3$
6	27.4	3.6	1.3	NIL	Nil	Nil	9.0	0.30	123.0	0.1	6.7	360.0	9.3	$1.7x10^3$
7	18.5	3.5	0.92	Nil	Nil	Nil	16.3	0.05	107.5	0.2	6.4	254.0	7.5	$2.1x10^3$
8	44.8	9.1	3.0	Nil	Nil	Nil	11.5	0.02	130.0	0.4	6.8	266.0	10.1	$1.8x10^{2.}$
9	13.8	12	1.3`	Nil	Nil	Nil	6.5	Nil	100.0	0.4	7.1	236.0	4.0	$2.1x10^{31}$
10	19.4	12.5	1.0	NIL	Nil	Nil	20.0	Nil	92.0	0.1	6.5	298.0	7.5	$2.1x10^3$
11	15.0	9.0	0.85	Nil	Nil	Nil	6.0	Nil	59.5	0.2	7.0	336.0	6.3	$6.3x10^3$
12	28.7	5.4	1.4	Nil	Nil	Nil	15.5	0.2	62.9	0.4	7.1	402.0	9.4	$1.9x10^3$
13	18.0	9.3	0.85	Nil	0.73	0.5	7.5	Trace	49.0	0.1	6.5	248.0	7.6	$5.3x10^2$
14	15.4	8.0	0.85	Nil	0.45	Nil	11.5	Nil	72.5	0.1	7.05	314.0	6.5	$1.5x10^3$
15	10.0	7.6	0.85	Nil	0.40	0.3	7.5	0.40	105.0	0.3	6.7	404.0	4.2	$1.6x10^3$
16	3.7	8.6	0.85	NIL	0.50	Nil	9.5	Nil	79.5	0.2	6.8	460.0	1.6	$x10^3$
17	5.0	10.6	0.58	Nil	0.30	Nil	9.5	Nil	57.0	0.2	6.2	544.0	2.1	$x10^3$
18	6.5	8.2	1.2	Nil	0.50	Nil	11.0	Nil	4.5	0.15	6.7	298.0	2.3	$6.7x10^3$
19	3.5	28.0	1.7	Nil	Nil	NIL	8.0	Nil	75.0	0.15	6.4	1026	1.0	$8.3x10^3$
20	11.0	6.2	0.85	Nil	Nil	Nil	11.0	NIL	51.5	0.1	6.6	325.0	4.6	$3.5x10^3$
21	31.1	14.2	1.1	NIL	Nil	Nil	13.5	Nil	100.0	0.4	6.9		11.5	$1.6x10^3$

Source: (Adesoye and Partners, 1999).

Appendix J: Water quality criteria for various uses

Use	Fe	Mg	Ca	Na	So_4^{2-}	No_3^-	$C1^-$	$HC0_3^-$	TDS	PH	Hardness
Domestic	0.2 0.5	20-100	40 100	100-300	100-300	-	-	150 400	300-2000	7-8.5	-
Irrigation	-	-	-	50-200	200-400	200-400	-	100-250	200-400	500-3000	-
Food	0.2	40	80	300	-	20	300	300	1000	-	-
Textile	0.25	-	-	-	-	-	-	-	2000	-	-
Cooling	0.5	-	-	-	-	-	-	-	-	-	50
Beverage	0.2 0.3	-	50-100	-	-	-	-	-	850	-	250
Brewing	0.1	-	75	-	-	-	-	-	500	6.5-7.5	-

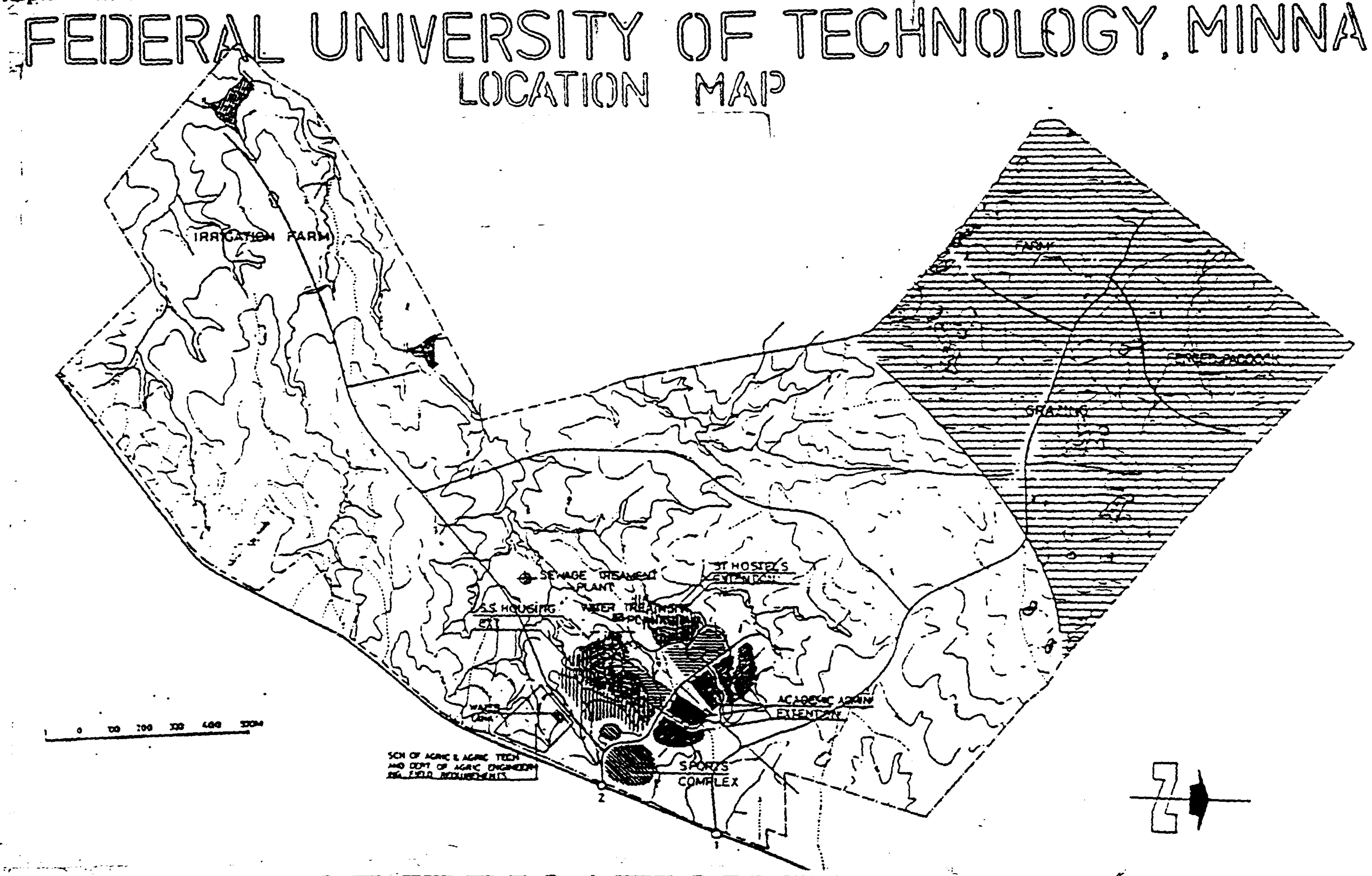
Source: (Adesoye and Partners, 1999).

Appendix K: Climatologically Report for Minna (2001)

Month	Rainfall (mm)	Max. temp. (^{0}c)	Min. temp. (^{o}c)	Relative Humidity	Mean Monthly Temp. (^{o}c)
JAN.	0.00	34.90	20.4-	31.10	27.65
FEB.	0.00	37.10	22.80	30.10	29.65
MAR	0.00	37.90	25.20	44.90	31.55
APR	93.90	36.30	24.40	57.00	30.35
MAY	139.00	33.70	24.20	61.00	28.95
JUNE	331.70	30.90	21.90	70.00	26.40
JULY	244.60	29.20	21.90	76.00	25.55
AUG	230.20	28.30	21.70	79.00	25.55
SEPT.	298.80	29.50	20.90	73.00	25.20
OCT.	25.27	33.00	19.10	43.70	26.55
DEC.	0.00	34.90	20.10	35.60	27.50

Source: Department of Meteorological services, Federal Min. of Aviation, Minna Airport, Niger State, (2001).

Appendix L



LOCATION OF IRRIGATION FARM

Source: Adesoye and Partners, (1999).

SITE FARM (PROJECT SITE)

MONTHS		MARCH					APRIL				MAY				JUNE					JULY			
WELLS	DEPTH	6th	10th	17th	24th	31st	7th	14th	21st	28th	5th	12th	19th	26th	2nd	9th	16th	23rd	30th	7th	14th	21st	28th
A	2.73	1.37	-1.40	-1.40	-1.42	-1.51	-1.57	-1.62	-1.39	-1.22	-1.20	0.25	0.17	-0.21	-0.90	0.23	0.23	0.26	0.25	0.20	0.26	0.26	-.25
B	2.69	2.52	-2.55	-2.56	-2.57	-2.60	-	-	-2.55	-2.40	- 1.76	-2.43	-2.46	-2.48	-2.56	-2.55	-1.50	-1.01	-1.02	-0.98	-0.96	-0.92	-0.52
C	1.26	-	-	-	-	-	-	-	-1.25	-1.23	-1.21	-1.18	-0.82	-0.89	-120	-1.18	-1.17	-1.19	-1.21	-0.84	-0.84	-0.74	-0.74

MONTHS		AUGUST				SEPTEMBER					OCTOBER				NOVEMBER				DECEMBER				
WELLS	DEPTH	4th	11th	18th	25th	1st	8th	15th	22nd	29th	6th	13th	20th	27th	3rd	10th	19th	24th	1st	8th	15th	22nd	28th
A		0.26	0.26	0.22	0.26	0.27	0.20	0.22	0.21	0.14	003	0.26	0.26	0.19	-0.12	-0.63	-0.83	-0.94					
B		-0.52	-0.71	-0.60	-0.54	-0.40	-0.50	-0.51	-0.62	-0.67	-0.66	-1.51	-0.71	-1.11	-2.00	-2.00	-	-					
C		-0.71	-0.80	-0.76	-0.65	-0.55	-0.78	-0.68	-0.65	-0.85	-0.88	-0.92	-0.94	-0.96	-	-	-						