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Groundwater Salinity Modeling Using Artificial Neural Networks

Gaza Strip case study

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بسم الله الرحمن الرحيم

﴿ رب أوزعني أن أشكر نعمتك التي أنعمت علي وعلى والدي وأن أعمل صالحا ترضاه وأدخلني برحمتك في عبادك الصالحين ﴾

(النمل الآية 19)

“O my Lord! So order me that I may be grateful for Thy favours, which Thou has bestowed on me and on my parents, and that I may work the righteousness that will please Thee: and admit me, by Thy Grace, to the ranks of Thy Righteous Servants”

Abstract

The main source of water in Gaza Strip is the shallow aquifer which is part of the coastal aquifer. The quality of the groundwater is extremely deteriorated in terms of salinity. Salinization of groundwater may be caused and influenced by many variables. Studying the relation of between these variables and salinity is often a complex and nonlinear process, making it suitable for Artificial Neural Networks (ANN) application.

In order to model groundwater salinity in Gaza Strip using ANN it is necessary to gather data for training purposes. Initially, it is assumed that the groundwater salinity (represented by chloride concentration, mg/l) may be affected by some variables as: recharge rate (R), abstraction (Q), abstraction average rate (Qr), life time (Lt), groundwater level Wl, aquifer thickness (Th), depth from surface to well screen (Dw), and distance from sea shore line (Ds). Data were extracted from 56 wells, most of them are municipal wells and they almost cover the total area of Gaza Strip.

The initial modeling trials were made using all input variables and many trials were applied to get best performance model. From the created ANN models, the importance and effect of each variables was studied and represented, also depending on the results of ANN models some input variables were neglected and new modeling trials are made without using neglected input variables.

After a number of trials, the best neural network was determined to be Multilayer Perceptron network (MLP) with four layers: an input layer of 6 neurons, first hidden layer with 10 neurons, second hidden layer with 7 neurons and the output layer with 1 neuron. The six input neurons are: initial chloride concentration (Cl_o), recharge rate (R), abstraction (Q), abstraction average rate of area (Qr), life time (Lt), aquifer thickness (Th). The output neuron gives the final chloride concentration (Cl_f).

The ANN model generated very good results depending on the high correlation between the observed and simulated values of chloride concentration. The correlation coefficient (r) was 0.9848. The high value of (r) showed that the simulated chloride concentration values using the ANN model were in very good agreement with the observed chloride concentration which mean that ANN model is useful and applicable for groundwater salinity modeling. ANN model was successfully utilized as analytical tool to study influence of the input variables on chloride concentration. It proved that chloride concentration in groundwater is directly affected by abstraction (Q), abstraction average rate (Qr) and life time (Lt). Furthermore, it was adversely affected by recharge rate (R) and aquifer thickness (Th). Furthermore, it is utilized as simulation and prediction tool of chloride concentration in domestic wells in Gaza Strip, the prediction of chloride concentration will be based on some scenarios of abstraction from groundwater. Also it will be used as a decision making support tool that suggests the appropriate abstraction from groundwater wells comparing with the status of salinity.

الخلاصة

تعتبر المياه الجوفية المصدر الرئيسي للمياه في قطاع غزة و هي معرضة للتلوث وخصوصاً فيما يتعلق بازدياد معدلات الملوحة التي تتواجد وتتأثر بالعديد من المتغيرات. إن دراسة العلاقة بين هذه المتغيرات و الملوحة عادةً ما تكون عملية معقدة مما يجلها مناسبة لتدرس و تنمذج من خلال الشبكات العصبية الصناعية.

إن نمذجة ملوحة المياه الجوفية من خلال الشبكات العصبية الصناعية تتطلب جمع البيانات اللازمة لعملية التدريب التي تقوم بها الشبكة العصبية. في البداية أفترض البحث أن ملوحة المياه الجوفية المتمثلة بكمية الكلوريد في المياه الجوفية تتأثر بعدة متغيرات هي معدل تسرب مياه الأمطار للخزان الجوفي و كمية السحب الخاصة بكل بئر ومعدل السحب من الخزان الجوفي و المدة الزمنية التي تعرض فيها الخزان الجوفي للسحب و منسوب المياه الجوفية و سمك الخزان الجوفي و عمق الخزان الجوفي عن سطح الأرض و المسافة بين منطقة السحب و البحر ولقد استخرجت هذه البيانات من 56 بئر مياه تغطي معظم مساحة قطاع غزة.

في البداية تمت عملية النمذجة باستخدام جميع المتغيرات المفترضة وقد تم تنفيذ عدة محاولات للحصول على نموذج يعطى نتائج جيدة و من النماذج التي تم تطويرها تم دراسة تأثير العوامل على تركيز الكلوريد في المياه الجوفية و بناء على الدراسة تبين أنه يمكن تجاهل بعض العوامل و تم عمل محاولات أخرى تبين من خلالها أن أفضل شبكة عصبية تم التوصل إليها هي Multilayer Perceptron network (MLP) و تتكون من أربع طبقات هي طبقة المدخلات و يوجد بها 6 نيورن و الطبقة المخفية الأولى و يوجد بها 10 نيورن و الطبقة المخفية الثانية و يوجد بها 7 نيورن وطبقة المخرجات و يوجد بها نيرون واحد. طبقة المدخلات تمثل العوامل التالية تركيز الكلوريد الابتدائي و معدل تسرب مياه الأمطار للخزان الجوفي و كمية السحب الخاصة بكل بئر ومعدل السحب من الخزان الجوفي و المدة الزمنية التي تعرض فيها الخزان الجوفي للسحب و سمك الخزان الجوفي أما طبقة المخرجات فتمثل تركيز الكلوريد النهائي.

لقد أعطت الشبكة العصبية نتائج ممتازة اعتماداً على التقارب الكبير بين القيم الحقيقة و القيم المستخرجة من النموذج حيث بلغت قيمة معامل الارتباط 0.9848 و هذا يعني أن هناك توافقا كبيراً بين القيم الحقيقة و القيم المستخرجة من النموذج مما يجعل النموذج صالحاً للاستخدام و التطبيق. تم استخدام النموذج بنجاح كأداة لدراسة تأثير العوامل على تركيز الكلوريد حيث تبين أن تركيز الكلوريد يتناسب طردياً مع كمية السحب الخاصة بكل بئر ومعدل السحب من الخزان الجوفي و المدة الزمنية التي تعرض فيها الخزان الجوفي للسحب و أنها تتناسب عكسياً مع معدل تسرب مياه الأمطار للخزان الجوفي و سمك الخزان الجوفي واستخدم النموذج كوسيلة للتنبؤ بتركيز الكلوريد لعدة سيناريوهات تدرس تأثير السحب من الخزان الجوفي على الملوحة في المستقبل كما استخدم النموذج كأداة لتحديد كمية السحب المسموح بها لتحسين الملوحة أو الحفاظ عليها ثابتة في كل بئر على حدة.

Dedication

Proudly, I dedicate my thesis to my parents, as I always feel their prayers in all aspects of my life, my beloved brothers, sisters, friends, colleagues. Finally special dedication to my wife Aisha and my lovely sons Adnan and Ibraheem.

Acknowledgements

First and foremost, I am grateful to my lord who has given me the strength, enablement, wisdom, knowledge and required understanding to complete this thesis.

Next, I wish to express my unreserved gratitude to my advisor, Dr. Yunes Mogheir, for his help. His constructive criticisms and ideas have made this project worth reading. To say am very privileged to have him as my advisor.

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I would like to thank the Islamic University of Gaza, Faculty of Engineering for providing me high standard of Education through the duration of a master program of Water Recourses Engineering.

I appreciate the support rendered by the staff of PWA and CMWU. They made the data used in this project available.

I would like to thank all those who have assisted, guided and supported me in my studies leading to this thesis.

Finally, I would like to extend my deepest gratitude to parents and my wife, they have always given me unremitting support during preparation my thesis.

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List of Abbreviations

Symbol	**Item**
ANN	Artificial Neural Networks
BBNs	Bayesian Belief Networks
BP	Back Propagation
CAMP	Coastal Aquifer Management Program
CMWU	Coastal Municipal Water Utility
GRNN	Generalized Regression Neural Networks
GA	Genetic algorithm
IAMP	Integrated Aquifer Management Plan
MOLG	Ministry of Local Governorates
MOPIC	Ministry of Planning and International Corporation
MLP	Multi-Layer Perceptrons
PCBS	Palestinian Central Bureau of Statistics
PNA	Palestinian National Authority
PWA	Palestinian Water Authority
RBF	Radial Basis Function
SNN	STATISTICA Neural Networks
TDS	Total Dissolved Solids
UNEP	United Nations Environment Programme
USAID	United State Agency for International Development
VMF	Visual Modflow
WHO	World Health Organization

Units and Measures

cubic meters per hour	m^3/hr
millgrams per liter	mg/l
million Cubic meter per year	Mm^3/y
year	y
Part per million	ppm
millimeter	mm
meter	m
kilometer	km
square meter	m^2
cubic meter	m^3
centimeter	cm
millimeter per square meter per month	mm/m^2/month

Chapter (1)

Introduction

1.1 Background

Water is essential for sustenance of life. The knowledge of the occurrence, replenishment and recovery of potable groundwater assumes special significance in quality-deteriorated regions, as Gaza Strip because of scarce presence of surface water. In addition to this, unfavorable climatic condition i.e. low rainfall with frequent occurrence of dry spells, high evaporation etc. on one hand and an unsuitable geological set up on the other, a definite limit on the effectiveness of surface and subsurface reservoirs. During recent years, stupendous growth of population and development of the area has compelled the authorities to adopt management practices for better conservation of water resources.

The main source of water in Gaza Strip is the shallow aquifer which is part of the coastal aquifer. The quality of the groundwater is extremely deteriorated in terms of salinity and nitrates. Salinity in the Gaza coastal aquifer is often described by the chloride concentration in groundwater. Depending on location and hydrochemical processes, rates of salinization may be gradual or sudden. (Metcalf and Eddy, 2000). It is concluded from the available data that few of the Gaza’s aquifer resources meets the World Health Organization (WHO) water standard for Chloride concentration (250 mg/l), which located primarily in the north and along the dune sand in the southwest areas

Salinization of groundwater may be caused by a number and/or combination of different processes, including: seawater intrusion, migration of brines from the deeper parts of the aquifer, dissolution of soluble salts in the aquifer (water-rock interaction), and contribution from discharges from older formations surrounding the coastal aquifer. In addition, potential man-induced (anthropogenic) sources include agricultural return flows, wastewater seepage, and disposal of industrial wastes (CAMP, 2000).

In addition, water quality (eg - salinization) is influenced by many factors such as flow rate, contaminant load, medium of transport, water levels, initial conditions and other site-specific parameters. The estimation of such variables is often a complex and nonlinear process, making it suitable for Artificial Neural Networks (ANN) application (Govindaraju et al., 2000).

ANN refer to computing systems whose central theme is borrowed from the analogy of biological neural networks. They represent highly simplified mathematical models of biological neural networks. They include the ability to learn and generalize from examples to produce meaningful solutions to problems even when input data contain errors or are incomplete, and to adapt solutions over time to compensate for changing circumstances and to process information rapidly (Jain et al., 2004).

The importance of this research is to develop ANN model studying the relation between groundwater salinity (represented by chloride concentration mg/l) and some hydrological variables as: recharge rate (R), abstraction (Q), abstraction average rate (Qr), life time (Lt), groundwater level (Wl), aquifer thickness (Th), depth from surface to well screen (Dw), and distance from sea shore line (Ds).

Understanding spatial relations between hydrological variables and salinity of groundwater can contribute in an integration of water resources management. Modeling groundwater salinity using traditional modeling softwares such as MT3D consume a lot of efforts and required huge quantity of data while ANN could provide an easy and efficient tool for modeling and prediction that help in water resources management. This research might be considered as one of the few contributions in quantitatively modeling of the relation between groundwater salinity and the hydrological variables in spatial scale using ANN.

1.2 Statement of the Problem

Although the safe yield of the Gaza's aquifer is only 100 Mm^3/y, the Palestinian consumption from the groundwater resources in the Gaza Strip in 2007 is about 170 Mm^3/y. This implies over-pumping of about twice of the safe yield, and consequently leads to the deterioration of the groundwater quality (PWA, 2007). Intensive exploitation of groundwater in the Gaza Strip in the past years, has disturbed the natural equilibrium between fresh and saline water, and has resulted in increasing salinity.

1.3 Objectives

The primary objective of this research is to develop ANN model studying the relation between groundwater salinity represented by chloride concentration in groundwater and some hydrological variables as: recharge rate (R), abstraction (Q), abstraction average rate (Qr), life time (Lt), groundwater level (Wl), aquifer thickness (Th), depth from surface to well screen (Dw), and distance from sea shore line (Ds).

After that, ANN model will be utilized in many practical and theoretical applications as follows:

- Analytical tool studying the influence of the input variables on chloride concentration.
- Simulation and prediction tool of chloride concentration on domestic wells in Gaza Strip.
- Decision making support tool.

1.4 Methodology

To achieve the objectives of this research, the following methodology will be applied:

- Data gathering from relevant institution and ministries
- Revision of accessible references as books, studies, papers and researches relative to the topic of this research which may include ANN, groundwater hydrology and groundwater salinity on Gaza Strip.
- Data analysis using software Ms. Excel and Access softwares. The analysis is required to construct some hundreds of data cases of input and output variables. Data cases are considered as row material to ANN model.
- Construction ANN model utilization STATISTICA Neural Networks (SNN) which built in STATISTICA program version 7. This step includes training, validation and testing ANN model. The validation and testing is achieved using SNN directly after training process.
- After testing ANN model, it is utilized in many practical and theoretical applications. It is utilized as analytical tool to study the influence of the input

variables on chloride concentration. Furthermore, it is utilized as simulation and prediction tool of chloride concentration on domestic wells in Gaza Strip. Finally it is utilized as a decision making support tool.

- SURFER program Version 8 is utilized to draw contour map of predicted chloride concentration for study well in Gaza Strip area.

The methodology is illustrated in the flow chart in Figure (1.1)

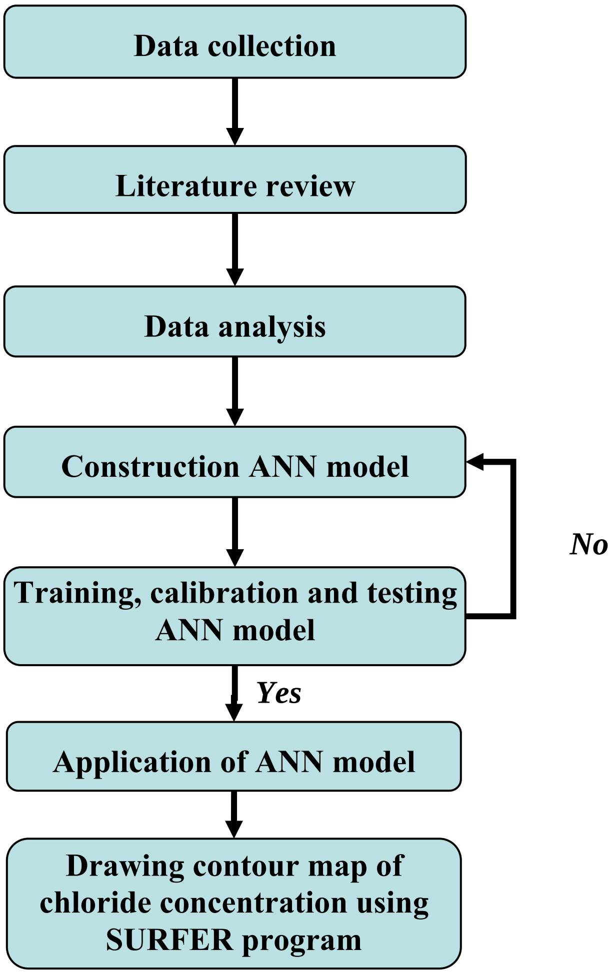

Figure (1.1): Flow chart of the research methodology

1.5 Thesis Outline

This thesis will be consist of seven chapters as follows:

Chapter One (Introduction): chapter one include a general background about groundwater salinity and ANN follows by statement of the problem, objectives, methodology used in order to achieve the objectives and thesis outline.

Chapter Two (Literature Review/ Groundwater Salinity): chapter two covers a general literature review on groundwater salinity including physico-chemical properties of salinity of groundwater, the effects and sources of groundwater salinity, then it talks about groundwater salinity in Gaza Strip and groundwater modeling process in Gaza strip. Finally it includes brief discussion of some available studies about groundwater modeling in Gaza Strip.

Chapter Three (Literature Review/ Artificial Neural Networks): chapter three presents a general literature review on ANN including brief introduction to ANN, history of ANN, architectures of ANN, types of ANN and then it presents the method of building ANN. Finally it discusses some ANN applications in hydrology fields

Chapter Four (Study Area Description): chapter four describes the study area with respect to its location, population, topography, climate and rainfall, land use geology and hydrology.

Chapter Five (Methodology): chapter five discuses the methodology of study including data collection and preparation, construction data matrix for ANN model and procedural steps in building ANN model.

Chapter Six (Results and Discussion): chapter six presents characters of initial and final ANN Model including topology, performance, regression statistics, response presentations, sensitivity analysis of ANN. Then it presents application of ANN model including utilization ANN model as analytical tool to study the influence of the input variables on chloride concentration, utilization ANN model as simulation and prediction tool of chloride concentration on domestic wells in Gaza Strip and utilization it as a decision making support tool.

Chapter Seven (Conclusions and Recommendations): chapter seven presents the main conclusions and recommendations of study.

Chapter (2)

Literature Review / Groundwater Salinity

2.1 Introduction

In many countries, especially in arid and semi arid regions as Gaza Strip, groundwater is one of the major water resources for domestic and agricultural uses. Aquifers and the contained groundwater are inherently susceptible to pollution from many sources (Abyaneh, 2005). Groundwater pollution can be described as degrading of water quality for any usage. In other words groundwater pollution is a modification of the physical, chemical and biological properties of groundwater. So, its use can be restricted or prevented. Substances that can pollute groundwater can be divided into two naturally occurring pollutants and pollutants produced by human activities (Sagnak, 2004). Salinity is one of the most widespread chemical pollutant of ground water. Saline water becomes unusable not only because of the bad taste but because it affects human health (eg. kidney function is affected by excessive salt intake) (Emmanuel et al., 2005).

Salinization may be caused by a number and/or combination of different processes, including: seawater intrusion; migration of brines from the deeper parts of the aquifer; dissolution of soluble salts in the aquifer (water-rock interaction); and contribution from discharges from older formations surrounding the coastal aquifer. In addition, potential man-induced (anthropogenic) sources include agricultural return flows, wastewater seepage, and disposal of industrial wastes (CAMP, 2000). In addition, water quality (eg - salinization) is influenced by many factors such as flow rate, contaminant load, medium of transport, water levels, initial conditions and other site-specific parameters (Govindaraju et al., 2000).

2.2 Physico-chemical Properties of Salinity of Groundwater

The salinity is closely related to the content sample chlorides. It is a particularly important concept for sea waters, certain industrial and underground water, especially the aquifers coastal. It definite as the sum of the solid matters in solution contained in a water, after conversion of carbonates into oxides, oxidation of all the organic matter and replacement of iodides and bromides by an equivalent quantity of chlorides. Chlorides, i.e. the sum of Cl- , Br -, I (Emmanuel et al., 2005).

Chloride (Cl-) is a negative ion of the element chlorine (Cl) and is widely distributed in the environment. It is present in water, soil, rock, and many foods. Chloride is found naturally in groundwater through the weathering and leaching of sedimentary rocks and oils and the dissolution of salt deposits. chloride is often attached to sodium, in the form of sodium chloride (NaCl) (NOVA, 2005).

The ions chlorides, in the Cl- shape represent one of the inorganic major anions in water. In drinking water the salted taste produces by the presence of ion chloride varies with the chemical composition of water; certain water containing 250 mg/L ions Cl- associated with the Na+ cation will have a salted savour. This savour will be marked in water containing approximately 1000 mg/L Cl associated with the dominant cations are Ca2+ and Mg2+ (Abyaneh, 2005). In this research it was assumed that groundwater salinity is represented by chloride concentration with unit mg/l.

The presence of salt in fresh water modifies some physical properties (density, compressibility, point freezing, temperature of the maximum of density). Whereas others (viscosity, absorption of the light) are influenced little. The quantity of salt in water directly influences electric conductivity and the osmotic pressure). The principal physico-chemical properties related to the salinity of water can be appreciated by measurements of the following parameters: chloride concentration, electric conductivity, solid total dissolved (TDS). Electric conductivity and the TDS are general indicators of salinity, in the sense that they account for the activity of all the bodies dissolved in water. The chloride concentration is specific indicator of water according to their content of TDS presented in Table (2.1) (Abyaneh, 2005).

Table (2.1): Classification of water according to their content of TDS (Emmanuel et al., 2005)

Type of water	TDS in mg/L
Fresh water	< 500
Slightly brackish water	1000 – 5000
Moderately brackish water	5000 – 15000
Very brackish water	15000 – 35000
Sea water	35000 – 42000

2.3 The Effects of Groundwater Salinity

Chloride itself in drinking water is generally not harmful on human beings. At concentrations higher than 250 mg/L, the sodium associated with chloride may be a concern to people on sodium restricted diet (NOVA, 2005). Taste threshold is about 250mg/1 for most people. Therefore, public drinking water standards require chloride levels not to exceed 250 mg/1 recommended World Health Organization (WHO) level (WHO, 2006). The principal effects of salinity on human health are gravidic toxaemia or preeclampsy, at the pregnant women, and hypertension (Abyaneh, 2005). Groundwater salinity may impact badly in various ways on domestic, industrial, community infrastructure, soils, plants and live stock especially pregnant females (Victorian, 2005). Chloride also contribute to the total dissolved solids (TDS) in drinking water this may affect the rate of corrosion of steel and aluminum. chloride may cause corrosion of some metals in pipes, pumps, fixtures, and hot water heaters (NOVA, 2005).

2.4 Sources of Groundwater Salinity

Salinity in groundwater may come from many processes such as dissolution of rocks containing chlorides, irrigation drainage, seawater intrusion in coastal aquifers, and salt water up coning of ancient seawater (connate water). Also, it may come from application of fertilizers or pesticides, effluent of wastewater treatment plants and industrial waste and from lateral movement of saline groundwater from up gradient areas of the aquifer, or upward movement from connected aquifers. Heavy pumping led to water level declines and changes in flow directions in the aquifers. In some cases, this has induced saline water from the sea or deep brines, to move into and contaminate an aquifer (CAMP, 2000). The sources of groundwater salinity can be divided into two naturally occurring pollutants and pollutants produced by human activities. The sources of salinity in ground water are illustrated in Figure (2.1).

2.4.1 Naturally Occurring Groundwater Pollution

2.4.1.1 Sea Water Intrusion

In the coastal plain where surface water is not enough and groundwater is limited, increasing water demand for tourism sector in addition to irrigation and domestic water supply is threat for groundwater. Finally, if groundwater is overexploited, sea water moves to the aquifer and quality of groundwater starts to deteriorate. Salt concentration increases (Sagnak, 2004).

2.4.1.2 Geothermal Affects

The chemical composition of groundwater is determined by composition of the materials it contacts and its duration. The longer contact period, the more minerals are dissolved. Especially, thermal water causes bad effects for fresh groundwater. It carries more minerals and materials deteriorating water quality. In addition this, during geothermal activities mineral water infiltrates. This is a big thread for unconfined aquifers (Sagnak, 2004).

2.4.1.3 Pollutants Originated From Geological Formation

Geological formation containing salt, gypsum, etc. In some groundwater basin, there are impervious barriers between fresh water bearing formations and salty water layers. When wrong drilling methods are used in these formations, salty water and fresh groundwater can be mixed and quality of fresh water can be deteriorated. A balance was established by the nature. But, in parallel to developing drilling activities, the balance has been affected due to wrong well construction. In order to prevent this, water movement among different aquifer systems should be studied and restricted.

2.4.2 Groundwater Pollution Produced by Human Activities

Pollution sources produced by human activities can be grouped into three general categories. These are municipal, industrial and agricultural disposal.

2.4.2.1 Municipal Disposal

Pollution sources may be point sources or non-point sources. In developing country, point sources are mainly municipal disposal due to fewer services such as poor sewerage systems. Rapid and uncontrolled urbanization over the areas that have groundwater potential is an important risk. In some areas, this may be more dangerous because of cracks, fractures and the high capacity of permeability. Also, the volume of municipal disposal is increasing day by day.

2.4.2.2 Industrial Disposal

Because many factories have been constructed on the aquifer systems and unfiltered waste water has been infiltrated to groundwater, heavy metal is analyzed in the groundwater. In order to minimize water pollution, waste water treatment plants have to be constructed. Besides, waste water should be stored in the waste water dam. So, seepage to the aquifer should be prevented or after treatment polluted water can be conveyed to disposal area.

2.4.2.3 Agricultural Pollutants

The use of pesticide and fertilizer is growing due to agricultural activities. This causes pollution. To prevent pollution, negatives affect of that activities should be controlled. Especially, groundwater recharge area must be estimated and the usage of chemicals must be prohibited in that area. In terms of areal extent, agriculture is one of the most widespread human activities (Sagnak, 2004).

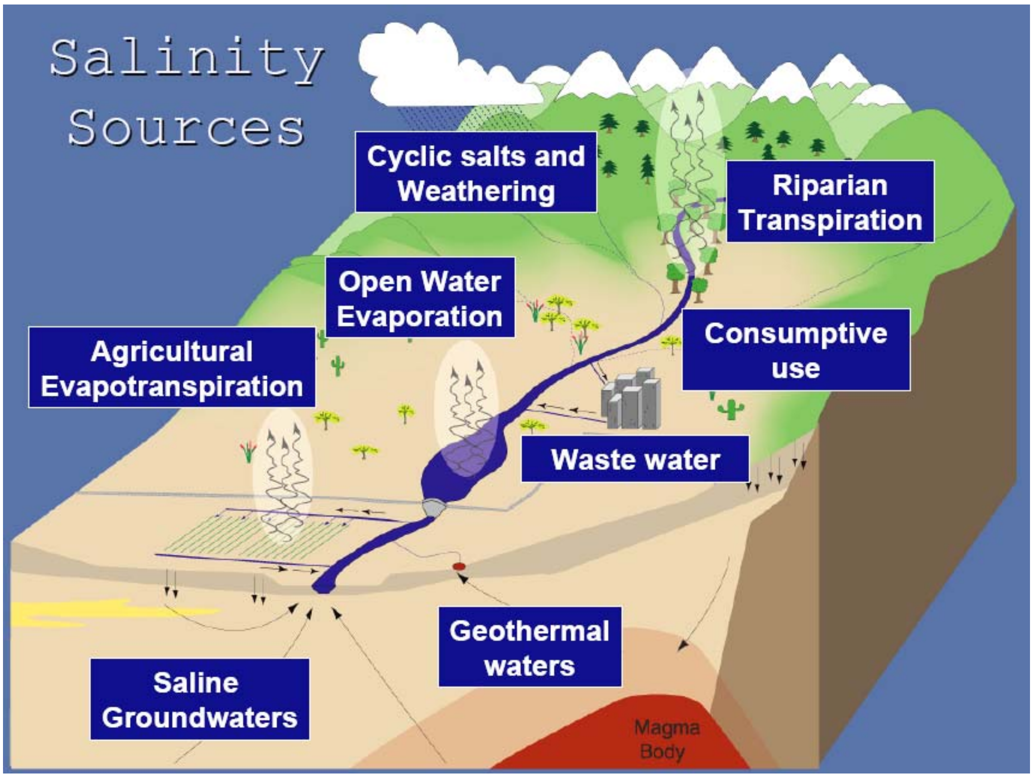

Figure (2.1): The sources of salinity in ground water (Phillips, 2005)

2.5 Groundwater Salinity in Gaza Strip

Gaza Strip is one of the places where the exploitation level of recourses exceeds the carrying capacity of the environment. This is especially true for the water and land resources, which are under high pressure and subject to sever over exploitation, pollution and degradation. Quality of the groundwater is a major problem in Gaza strip. The aquifer is highly vulnerable to pollution. The domestic water is becoming more saline every year and average chloride concentrations of 500 mg/l or more is no longer an exception. Most of the public water supply wells don't comply with the drinking water quality standards and concentrations of chloride and nitrate of the water exceed the World Health Organization (WHO) standards in most drinking water wells of the area and represent the main problem of groundwater quality. Over pumping of groundwater and salt water intrusion are the main reasons behind high chloride concentration (CAMP, 2000). Ground water is the only source of water in Gaza Strip, and many estimation of the annual groundwater recharge in the Gaza Strip have been mentioned in different references. Although different values for this recharge are given, all of these references agree on one fact, that the annual recharge is less than the abstracted quantities for along time, resulting in a serious mining of the groundwater resources and a net deficit of about 60 Million cubic meter (MCM)/year (CMWU, 2007). The deficit in the water balance has led to depletion and salinization of the available groundwater resources (PWA, 2005).

These processes deteriorated the water quality till it reached in many areas a point that it couldn't be used for drinking or even for irrigation It is clearly noticed that the chloride concentration increases significantly over all Gaza Strip especially in southern east and middle area. The best water quality is found in the sand dune areas in the north, mainly in the range of 50 – 250 mg/l. Figures (2.2) and (2.3) present average chloride concentration of pumped Groundwater of Gaza Strip for the year 2002 and 2007.

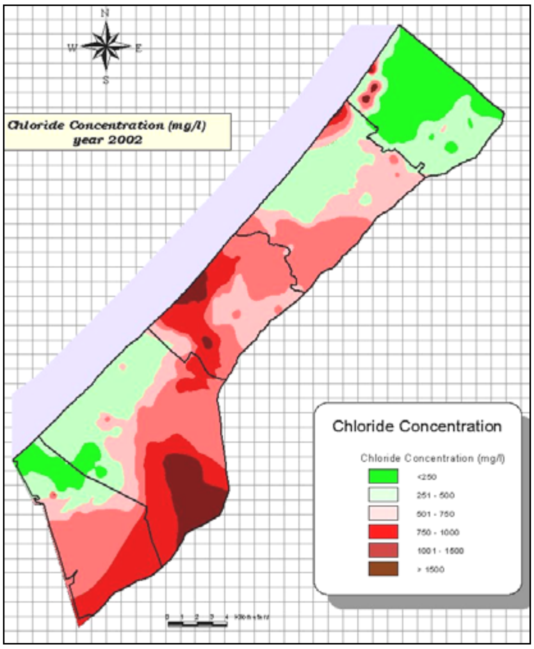

Figure (2.2): Average chloride concentration of pumped groundwater of Gaza Strip for the year 2002 (PWA, 2003)

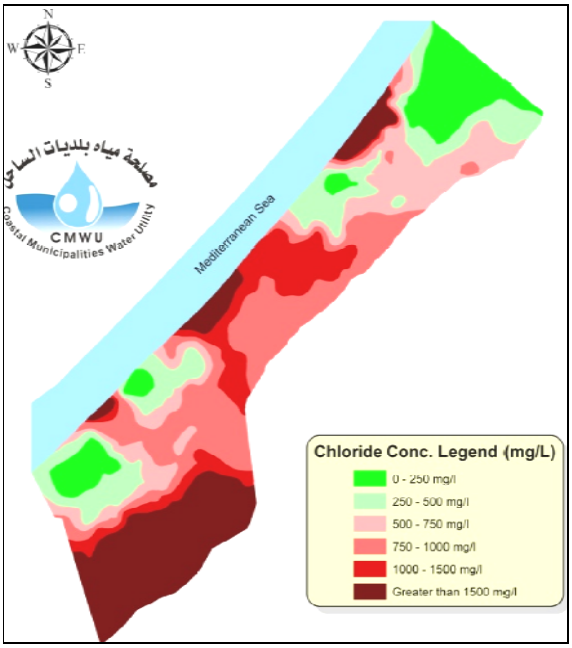

Figure (2.3): Average chloride concentration of pumped groundwater of Gaza Strip for the year 2007 (CMWU, 2007)

2.6 Groundwater Modeling

In recent years, groundwater modeling has become a principal part of many projects and studies dealing with groundwater exploitation, protection and remediation. Therefore, the groundwater model is considered as a best management tool for water resources; aims to regulate and optimize annual groundwater extraction without adversely impacting groundwater. This new technique is based on assumptions and approximations that simplify the actual system and cannot simulate exactly the inherent complexity of the hydrogeological framework. Therefore, the results of the any model simulation are only an approximation or and expectation of actual conditions and are only as accurate or realistic as the assumptions and data used in its development (PWA, 2005).

2.6.1 Groundwater Modeling in Gaza Strip

Since its establishment in 1995, Palestinian Water Authority (PWA) has forced to use this modern technique in water resources management program in order to simplify the complex hydrogeologic situation of groundwater aquifers and tries to understand the water regime within the entire aquifers. The ultimate goals of the (PWA) is to produce a long-term management plan that will provide rational and practical tools for management of groundwater extraction in Gaza Strip and West Bank aquifers and to identify the most potential zones that are suitable for future development (PWA, 2005).

In recognition the worsening situation of the water in Gaza Strip, PWA and United State Agency for International Development (USAID) have jointly developed the implementation of an Integrated Aquifer Management Plan (IAMP). The IAMP presented overall planning guidelines for water supply and usage through year 2020. As a result to this jointly, new model depending on Coupled Flow-Transport Modeling Code (DYNCFT) was conducted to simulate the effect of IAMP. DYNCFT is a model able to simulate 3-dimensional contaminant transport with dispersion and first-order decay and/or linear equilibrium adsorption. Conservative constituents (such as chloride and tritium) may be simulated as well. DYNCFT is based on the Lagrangian approach ('Random Walk" method for statistically significant number of particles, each particle having an associated weight, decay rate, and retardation). DYNCFT can also be used for transport modeling of dissolved contaminants, without variable density fluids. With the existing model PWA has an added capability to manage its resource, and equally importantly, to demonstrate what will happen if required investment are not made (Moe et al., 2001).

There are some researchers attempted to model the groundwater in Gaza Strip. Aish (2004) used GIS and MODFLOW in Artificial Recharge Modeling of the Gaza Coastal Aquifer. This research work investigates the first phase of a feasibility study on the impact of artificial recharge from a planned wastewater treatment plant on the groundwater quantity and quality of the coastal aquifer in the Gaza Strip. In the analysis of the results, the 100 mg/l of solute will be considered as the reference concentration (100% injected water) and the simulated concentration in the aquifer will be expressed relative to this value. The results indicate that 90% of the infiltrated water will be mixed with the aquifer water after 1 year beneath the recharge area with decreasing percentages in the surrounding area (Aish, 2004).

Ghabayen (2004) developed a model using Bayesian belief networks (BBNs), for Identification of salinity origin. The BBN model incorporates the theoretical background of salinity sources, area specific monitoring data that are characteristically incomplete in their coverage, expert judgment, and common sense reasoning to produce a geographic distribution for the most probable sources of salinization. The model showed areas where additional data on chemical and isotopic parameters are needed to understand the contribution of each of these sources to the problem. The model has successfully identified areas where seawater intrusion, deep brines, wastewater leakage, agricultural return flows, and Eocene waters exist with high probability. It has also identified areas where there is missing information or incomplete data especially in the eastern part of the coastal aquifer outside Gaza Strip (Ghabayen et al., 2004).

Qahman (2004) achieve a numerical assessment of seawater intrusion in Gaza Strip by applying a 3-D variable density groundwater flow model. A two-stage finite difference simulation algorithm was used in steady state and transient models. SEAWAT computer code was used for simulating the spatial and temporal evolution of hydraulic heads and solute concentrations of groundwater. A regular finite difference grid with a 400 m^2 cell in the horizontal plane, in addition to a 12-layer model were chosen. The model has been calibrated under steady state and transient conditions. Simulation results indicate that the proposed schemes successfully simulate the intrusion mechanism. Two pumpage schemes were designed to use the calibrated model for prediction of future changes in water levels and solute concentrations in the groundwater for a planning period of 17 years. The results show that seawater intrusion would worsen in the aquifer if the current rates of groundwater pumpage continue. The alternative, to eliminate pumpage in the intruded area, to moderate pumpage rates from water supply wells far from the seashore and to increase the aquifer replenishment by encouraging the implementation of suitable solutions like artificial recharge, may limit significantly seawater intrusion and reduce the current rate of decline of the water levels (Qahman et al., 2004).

Barakat (2005) developed a model to find optimal values of water quantities from different resources in in the southern Gaza Strip. Visual Modflow (VMF) and its integrated modules, was developed to quantify, and analyze the raw input data. Many scenarios for domestic supply and demand reconfiguration are introduced. Genetic algorithm (GA) is used as a global optimization method, to find optimal values of water quantities from different resources. The resulted optimal values for water quantities were introduced into the groundwater model to predict water level contour maps in the next years (Barakat, 2005).

The use of ANN in groundwater quality modeling in Gaza Strip doesn't found in large scale, Till now, only one researcher used it. Al Mahalawi used ANN in Modeling Groundwater Nitrate Concentration of the Gaza Strip (Mahalawi, 2007). My new research (Groundwater Salinity Modeling Using Artificial Neural Networks - Gaza Strip case study) might be considered as one of the few contributions in quantitatively modeling of the relation between groundwater salinity and the hydrological variables in spatial scale using ANN.

Chapter (3)
Literature Review/Artificial Neural Networks

3.1 Introduction to Artificial Neural Networks

ANN refer to computing systems whose central theme is borrowed from the analogy of biological neural networks. They represent highly simplified mathematical models of biological neural networks. They include the ability to learn and generalize from examples to produce meaningful solutions to problems even when input data contain errors or are incomplete, and to adapt solutions over time to compensate for changing circumstances and to process information rapidly (Jain et al., 2004).

The brain consists of a large number of neurons, connected with each other by synapses. These networks of neurons are called neural networks, or natural neural networks. ANN is a simplified mathematical model of a natural neural network. ANN are a new information-processing and computing technique inspired by biological neuron processing (Lee et al., 1998). The human brain provides proof of the existence of massive neural networks that can succeed at those cognitive, perceptual, and control tasks in which humans are successful. The brain is capable of computationally demanding perceptual acts (e.g. recognition of faces, speech) and control activities (e.g. body movements and body functions). The advantage of the brain is its effective use of massive parallelism, the highly parallel computing structure, and the imprecise information-processing capability. The human brain is a collection of more than 10 billion interconnected neurons. Each neuron is a cell that uses biochemical reactions to receive, process, and transmit information (Ajith, 2005). Figure (3.1) presented mammalian neuron.

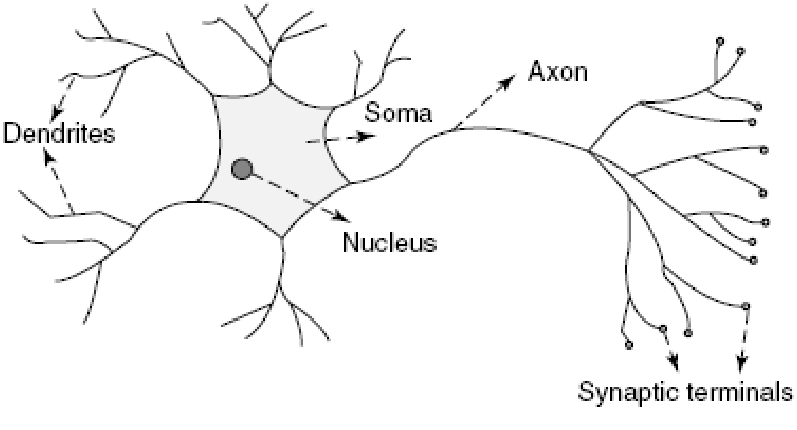

Figure (3.1): Mammalian neuron (Ajith, 2005)

Treelike networks of nerve fibers called dendrites are connected to the cell body or soma, where the cell nucleus is located. Extending from the cell body is a single long fiber called the axon, which eventually branches into strands and sub strands, and are connected to other neurons through synaptic terminals or synapses. The transmission of signals from one neuron to another at synapses is a complex chemical process in which specific transmitter substances are released from the sending end of the junction. The effect is to raise or lower the electrical potential inside the body of the receiving cell. If the potential reaches a threshold, a pulse is sent down the axon and the cell is 'fired' (Ajith, 2005).

Artificial neurons connected together form a network. The structure of ANN is, as rule, layered. Three functional group can be distinguished in the ANN ie the inputs receiving signals from the network's outside and introducing them into its inside, the neuron which process information and the neurons which generate results. A model of the artificial neuron is shown in the Figure (3.2). The model include N inputs, one output, a summation block and an activation block (Hola and Schabowicz, 2005).

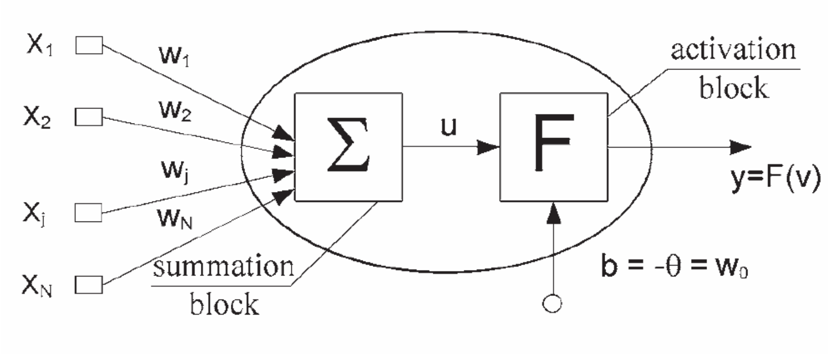

Figure (3.2): Model of artificial neurons (Hola and Schabowicz, 2005)

ANN is an informational system simulating the ability of a biological neural network by interconnecting many simple artificial neurons . The neuron accepts inputs from a single or multiple sources and produces outputs by simple calculations, processing with a predetermined non-linear function (Jeng et al., 2003).

The network topology consists of a set of nodes (neurons) connected by links and usually organized in a number of layers. Each node in a layer receives and processes weighted input from a previous layer and transmits its output to nodes in the following layer through links. Each link is assigned a weight, which is a numerical estimate of the connection strength. The weighted summation of inputs to a node is converted to an output according to a transfer function .

Most ANN has three layers or more: an input layer, which is used to present data to the network; an output layer, which is used to produce an appropriate response to the given input; and one or more intermediate layers, which are used to act as a collection of feature detectors. Determination of appropriate network architecture is one of the most important, but also one of the most difficult, tasks in the model-building process. Unless carefully designed an ANN model can lead to over parameterization, resulting in an unnecessarily large network (Sudheer et al., 2002). Figure (3.3) demonstrated schematic description of a general ANN model of three layers.

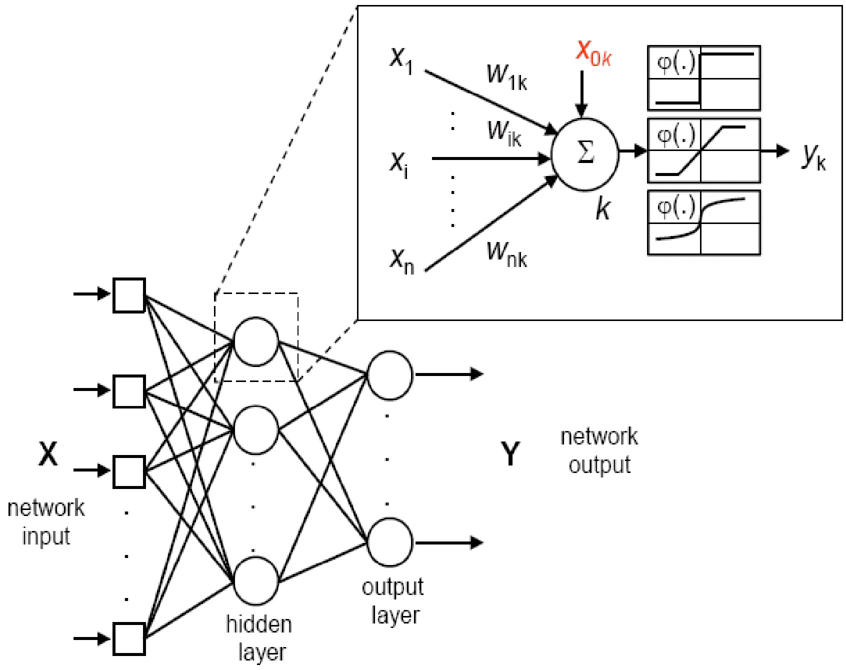

Figure (3.3): Schematic description of a three layer ANN and of the elements of its (mathematical) neurons (Claudius et al., 2005)

3.2 History of Artificial Neural Networks

A first wave of interest in ANN emerged after the introduction of simplied neurons by McCulloch and Pitts in 1943. These neurons were presented as models of biological neurons and as conceptual components for circuits that could perform computational tasks (Krose et al., 1996).

Hebb's book, 1949 presented the physiological learning rule for synaptic modification for the first time. Hebb proposes that the connectivity of the brain is continually changing as an organism learns differing functional tasks, and that neural assemblies are created by such changes. Rosenblatt 1958 introduced Perceptron which is novel method of supervised learning using perceptron convergence theorem. When Minsky and Papert published their book Perceptrons in 1969 (Minsky & Papert, 1969) in which they showed the deficiencies of perceptron models, most neural network funding was redirected and researchers left the field. Only a few researchers continued their efforts, most notably Teuvo Kohonen, Stephen Grossberg, James Anderson, and Kunihiko Fukushima (Krose et al., 1996).

The interest in neural networks re-emerged only after some important theoretical results were attained in the early eighties (most notably the discovery of error back-propagation), and new hardware developments increased the processing capacities. This renewed interest is reflected in the number of scientists, the amounts of funding, the number of large conferences, and the number of journals associated with neural networks (Krose et al., 1996).

Hopfield, 1982 showed how to use store information in dynamically stable networks. His work paved the way for physicists to enter neural modeling , thereby transforming the field of neural networks. Rumelhart, Hinton, and Williams 1986 developed the back-propagation algorithm, the most popular learning algorithm for the training of multilayer perceptrons. It has been the workhorse for many neural network applications at that time. Since the late 1980s, ANN has been used successfully to model a variety of different functions. The network is able to learn these functions intelligently through an automatic training process (Lee et al., 1998).

Over the past decade, ANN has become increasingly popular in many disciplines as a problem solving tool. ANN have the ability to solve extremely complex problems with highly non-linear relationships. ANN's flexible structure is capable of approximating almost any input-output relationships. Particularly ANN have been extensively used as a predicting and forecasting tool in many disciplines (Rajanayaka et al. , 2001). Nowadays most universities have a ANN group, within their psychology, physics, computer science, or biology departments (Krose et al., 1996).

3.3 Architectures of Artificial Neural Network

There are many ANN architectures, this property give ANN ability to solve a deferent models of data.

3.3.1 Simple Neuron (a single scalar input)

The central idea of ANN is that such parameters (weight, w & bias, b) can be adjusted in each training iterations. The neuron may be with or without bias.

3.3.1.1 Neuron Without Bias

The scalar input p is transmitted through a connection that multiplies its strength by the scalar weight w, to form the product wp, again a scalar. f is a transfer function (typically a step function or a sigmoid function). A neuron without bias is shown in Figure (3.4).

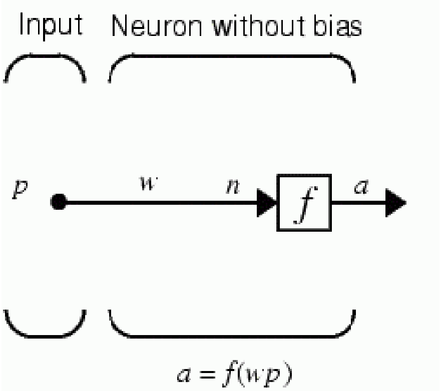

Figure (3.4): Neuron without bias (Matlab, 1994)

3.3.1.2 Neuron With Bias

This neuron has a scalar bias, *b* (is not an input) as simply being added to the product *wp*. A neuron with bias is shown in Figure (3.5).

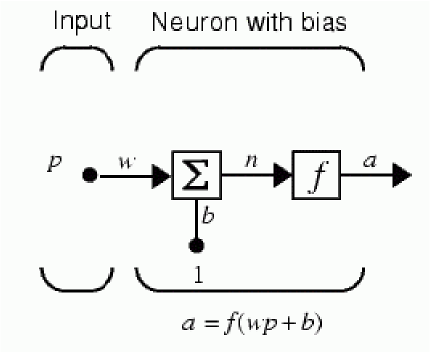

Figure (3.5): Neuron with bias (Matlab, 1994)

3.3.2 Neuron With Vector Input

A neuron with a single R-element input vector is shown in Figure (3.6).

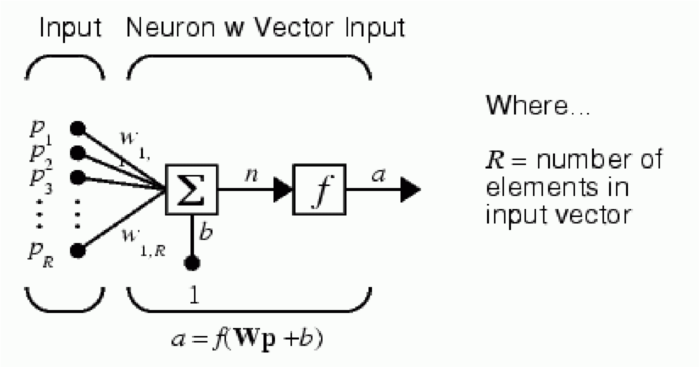

Figure (3.6): Neuron with Vector Input (Matlab, 1994)

Here the individual element inputs

$P_1, P_2, \ldots P_R$

Are multiplied by weights

$w_{1,1}, w_{1,2}, \ldots w_{1,R}$

Their sum is simply Wp, the dot product of the (single row) matrix W and the vector p.

The neuron has a bias ***b***, which is summed with the weighted inputs to form the net input , n .

$n = w_{1,1} P_1 + w_{1,2} P_2 + \ldots + w_{1,R} P_R + b$

3.3.3 Layers of Neurons

3.3.3.1 Perceptron Network

A one-layer network with R input elements and S neurons called perceptron network. In this network, each element of the input vector p is connected to each neuron input through the weight matrix W. A layer is not constrained to have the number of its inputs equal to the number of its neurons. The neuron layer outputs form a column vector a.

The need is to make a distinction between weight matrices that are connected to inputs and weight matrices that are connected between layers. Weight matrices connected to inputs are called input weights. Weight matrices coming from layer outputs are called layer weights. Perceptron Network is shown in Figure (3.7).

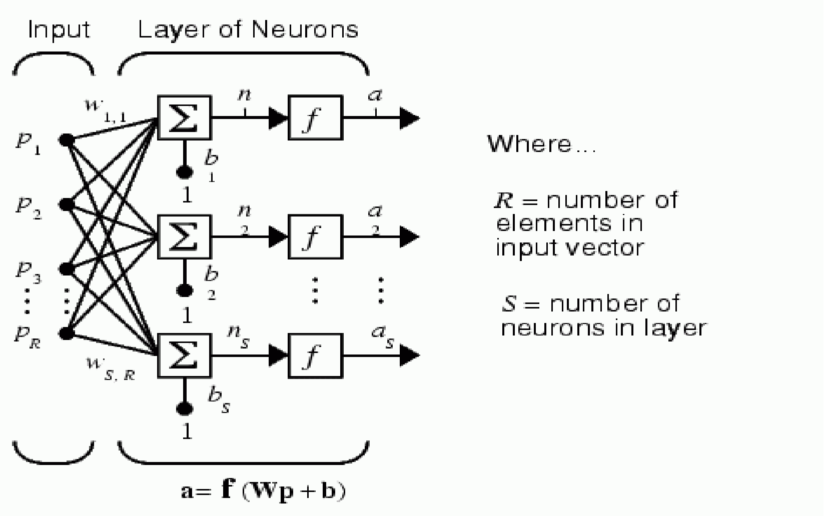

Figure (3.7): Perceptron network (Matlab, 1994)

3.3.3.2 Multiple Layers of Neurons

A network can have several layers. Each layer has a weight matrix W, a bias vector b, and an output vector a. the three-layer network shown in Figure (3.8). The layers of a multilayer network play different roles. A layer that produces the network output is called an output layer. All other layers are called hidden layers. The three-layer network shown in Figure (3.8) has one output layer (layer 3) and two hidden layers (layer 1 and layer 2).

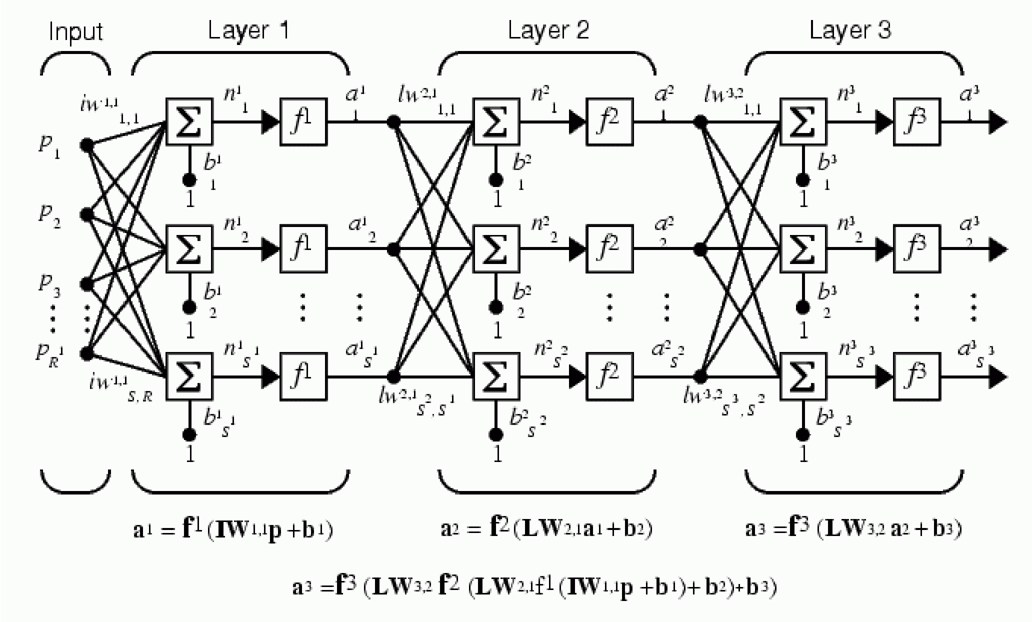

Figure (3.8): Multiple Layers of Neurons (Matlab, 1994)

3.4 Artificial Neural Networks Learning

There are several types of ANN learning. Supervised and unsupervised learning probably being the most important. In general, an ANN learns or is trained by adjusting the connection weights parameters, that link the neurons.

For classification and regression tasks supervised learning is used , where the available data set consists of corresponding input and output values representing a characteristic pattern or underlying functional behaviour. This data set is the so-called training set. The adaptation of the weights is carried out by an optimization algorithm that tries to minimize a difference or error measure between the ANN output based on the training set input values and their corresponding training set output value(s) (Govindaraju et al., 2000).

In unsupervised learning, the training of the network is entirely data-driven and no target results for the input data vectors are provided. ANN of the unsupervised learning type, such as the self-organizing map, can be used for clustering the input data and find features inherent to the problem. Unsupervised learning allegedly involves no target values. In fact, for most varieties of unsupervised learning, the targets are the same as the inputs (Sarle, 1994). In other words, unsupervised learning usually performs the same task as an auto-associative network, compressing the information from the inputs (Deco and Obradovic, 1996).

3.5 Types of Artificial Neural Networks

When Neural networks are trained, a particular input leads to a specific target output. Such a situation is shown Figure (3.9) There, the network is adjusted, based on a comparison of the output and the target, until the network output matches the target. Typically many such input/target pairs are used, in this supervised learning, to train a network.

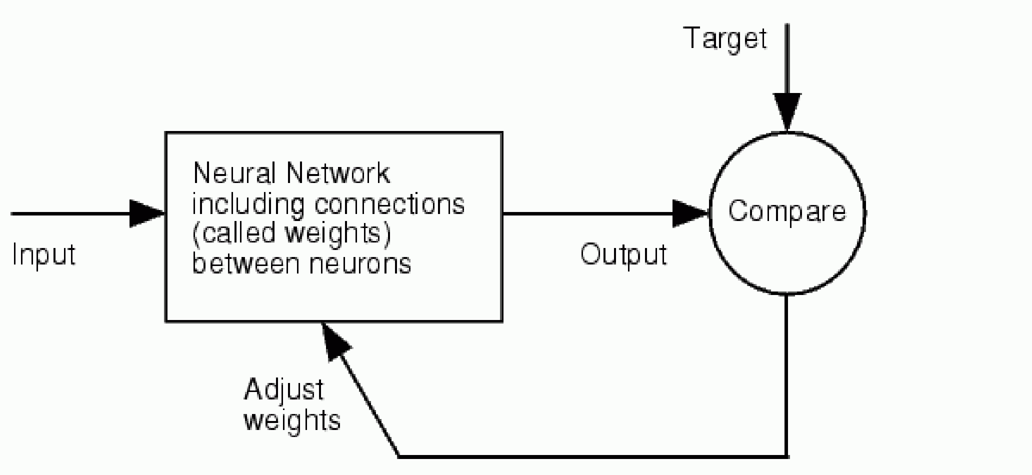

Figure (3.9): Neural Network Mechanism (Matlab, 1994)

The network adopts as follows, change the weight by an amount proportional to the difference between the desired output and the actual output. As an equation

$$\text{Delta } W_i = L * (D\text{-}Y).I_i$$

Where L is the learning rate, D is the desired output, and Y is the actual output.

This is called the **Perceptron Learning Rule**, and goes back to the early 1960's. Back-Propagation (BP) witch sometimes known as multi-layer perceptrons (MLP) and Radial Basis Function Networks (RBF) are both well-known developments of the Delta rule for single layer networks that is a development of the Perceptron Learning Rule. There are many other methods of training as the Generalized Regression Neural Networks (GRNN) and Hopfield Networks. In this study only (MLP) and (RBF) were used in modeling process.

3.5.1 The Back Propagation (BP) Method

Back Propagation (BP) witch sometimes known as multi-layer perceptrons (MLP) distinguishes itself by the presence of one or more hidden layers, whose computation nodes are correspondingly called hidden neurons of hidden units. The function of hidden neurons is to intervene between the external input and the network output in some useful manner. By adding one or more hidden layers, the network is able to extract higher order statistics. In a rather loose sense, the network acquires a global perspective despite its local connectivity due to the extra set of synaptic connections and the extra dimension of the network interconnections (Haykin, 1994).

The ability of hidden neurons to extract higher order statistics is particularly valuable when the size of the input layer is large. The source nodes in the input layer of the network supply respective elements of the activation pattern (input vector), which constitute the input signals applied to the neurons (computation nodes) in the second layer (i.e., the first hidden layer). The output signals of the second layer are used as inputs to the third layer, and so on for the rest of the network. Typically, the neurons in each layer of the network have as their inputs the output signals of the preceding layer only. The set of the output signals of the neurons in the output layer of the network constitutes the overall response of the network to the activation patterns applied by the source nodes in the input (first) layer. (BP) are trained using the Levenberg–Marquardt optimization technique. Throughout all (BP) simulations, the learning rate and the momentum rate parameters were taken adaptively (Cigizoglu et al. , 2007). Generally the Figure (3.8) show the Architectures of back propagation method.

Training BP Networks

The weight change rule is a development of the perceptron learning rule. Weights are changed by an amount proportional to the error at that unit times the output of the unit feeding into the weight. Running the network consists of

1- Forward pass:

The outputs are calculated and the error at the output units calculated.

2- Backward pass:

The output unit error is used to alter weights on the output units. Then the error at the hidden nodes is calculated (by back-propagating the error at the output units through the weights), and the weights on the hidden nodes altered using these values.

For each data pair to be learned a forward pass and backwards pass is performed. This is repeated over and over again until a given number of epochs elapse, or when the error reaches an acceptable level, or when the error stops improving (you can select which of these stopping conditions to use).

3.5.2 The Radial Basis Function-Based Neural Networks (RBF)

RBF were introduced into the neural network by Broomhead and Lowe in 1988. The RBF consists of two layers whose output nodes form a linear combination of the basis functions. The basis functions in the hidden layer produce a significant non-zero response to input stimulus only when the input falls within a small localized region of the input space. Hence, this paradigm is also known as a localized receptive field network.

Transformation of the inputs is essential for fighting the curse of dimensionality in empirical modeling. The type of input transformation of the RBF is the local nonlinear projection using a radial fixed shape basis function. After nonlinearly squashing the multi-dimensional inputs without considering the output space, the radial basis functions play a role as regressors. Since the output layer implements a linear regressor the only adjustable parameters are the weights of this regressor. These parameters can therefore be determined using the linear least square method, which gives an important advantage for convergence (Cigizoglu et al. , 2007).

Radial basis networks consist of two layers: a hidden radial basis layer of S^1 neurons, and an output linear layer of S^2 neurons as shown in Figure (3.10).

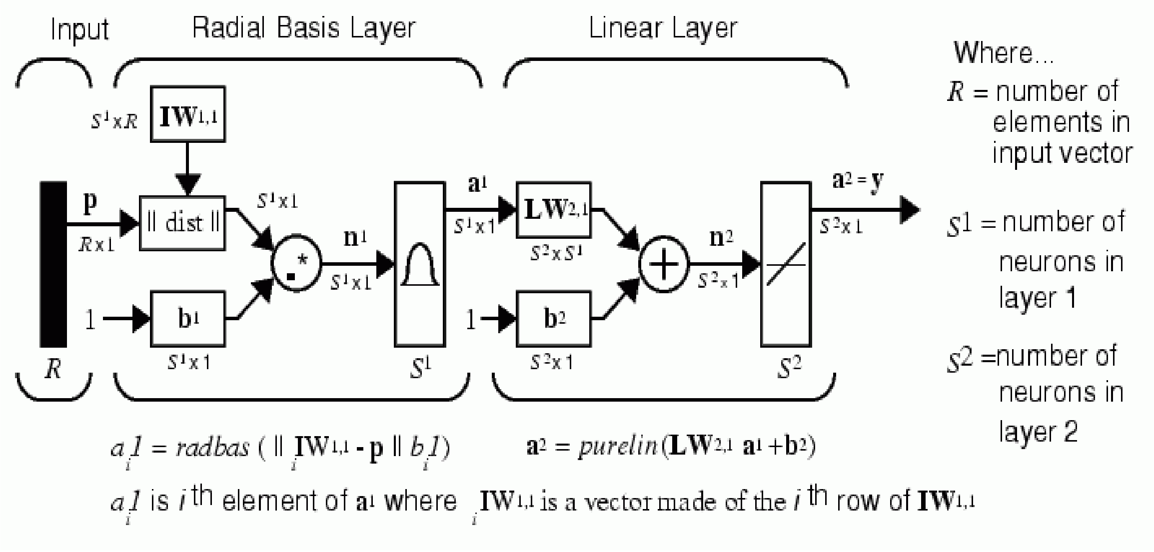

Figure (3.10): Radial Basis function Networks (Matlab, 1994)

3.6 Building Artificial Neural Networks

One of the critical issues in training the ANN model is to select input variables that are highly correlated with studied problem. The choice of variables (at least initially) is guided by intuition. Understanding and expertise in the problem domain and conditions gives initially idea of which input variables are likely to be influential. Once in ANN, variables can be selected and deselect, and ANN can also determine useful variables (Jiang and Cotton, 2004).

After selecting variables, the following procedure must be achieved to build any Artificial neural networks

- **Determine the network properties:**

  The network topology (connectivity), the types of connections, the order of connections, and weight range.

- **Determine the node properties:**

  The activation range and the activation (transfer) function.

- **Determine the system dynamics:**

  The weight initialization scheme, the activation-calculating formula, and the learning rule.

- **Determine the topology of a neural network:**

  The topology of a neural network refers to its framework as well as its interconnection scheme. The number of layers and the number of neuron (or nodes) per layer often specify the framework. The types of layers include in the network are:

  1- The input layer:

  The nodes in it are called input units, which encode the instance data presented to the network for processing. For example, each input unit may be designated by an attribute value possessed by the instance.

  2- The hidden layer:

  The nodes in it are called hidden units, which are not directly observable and hence hidden , They provide nonlinearities for the network.

  3- The output layer:

  The nodes in it are called output units, which encode possible concepts (or values) to be assigned to the instance under consideration. For example, each output unit represents a class of objects.

  A random sample of neural network that contain of three layers: an input layer of 4 neurons, one hidden layer of 7 neurons and an output layer of 1 neuron, as shown in Figure (3.11).

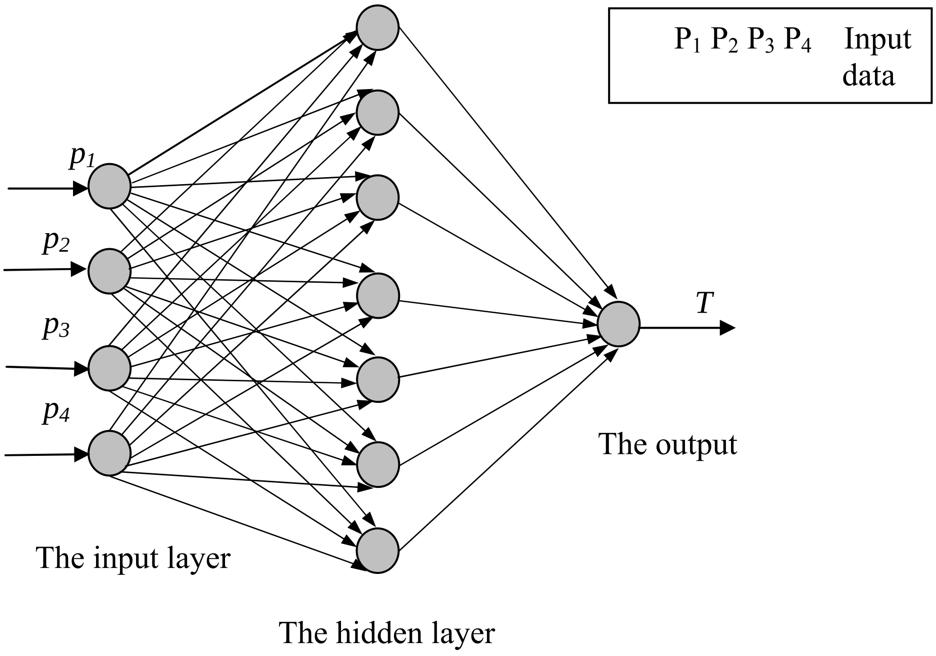

Figure (3.11): Random sample of neural network

In most situations, there is no way to determine the best number of hidden units without training several networks and estimating the generalization error of each. If you have too few hidden units, you will get high training error and high generalization error due to underfitting and high statistical bias. If you have too many hidden units, you may get low training error but still have high generalization error due to overfitting and high variance. So the best number of hidden layers depends in a complex way on:

- The numbers of input and output units.
- The number of training cases.
- The amount of noise in the targets.
- The complexity of the function or classification to be learned.
- The architecture of neural network
- The type of hidden unit activation function.
- The training algorithm.

3.7 Artificial Neural Networks applications in Hydrology

Over the past decade, ANN has become increasingly popular in many disciplines as a problem solving tool. ANN has the ability to solve extremely complex problems with highly non-linear relationships. ANN's flexible structure is capable of approximating almost any input-output relationships. Particularly ANN have been extensively used as a predicting and forecasting tool in many disciplines (Rajanayaka et al., 2001). Hydrologists are often confronted with problems of prediction and estimation of runoff, precipitation, contaminant concentrations, water stages, and so on most hydrologic processes exhibit a high degree of temporal and spatial variability and are further plagued by issues of nonlinearity of physical processes, conflicting spatial and temporal scales, and uncertainty in parameter estimates.

Our understanding in many areas is far from perfect, so that empiricism plays an important role in modeling studies. Hydrologists attempt to provide rational answers to problems that arise in design and management of water resources. An attractive feature of ANN is their ability to extract the relation between the inputs and outputs of a process, without the physics being explicitly provided to them. They are able to provide a mapping from one multivariate space to another, given a set of data representing that mapping. Even if the data is noisy and contaminated with errors, ANN has been known to identify the underlying rule. These properties suggest that ANN may be well-suited to the problems of estimation and prediction in hydrology (Govindaraju et al., 2000).

Applications of ANN to hydrology are rapidly gaining popularity due to their power and potential in mapping nonlinear system data The neural network technology has provided many promising results in the field of hydrology and water resources simulation. In recent years, ANN has found a number of applications in the area of water quality modeling (Govindaraju et al., 2000). Applications of ANN to hydrology are rapidly gaining popularity due to their power and potential in mapping nonlinear system data (Jain et al., 2004).

In recent years, ANN has provided many promising results in the field of hydrology. ANN was used in many hydrologic applications as rainfall forecasting (Hung et al., 2008), rainfall-runoff relationship (Junsawang et al., 2007), Evaporation modeling (Sudheer et al., 2002), and improving air temperature prediction (Smith et al., 2005).

The artificial neural network ANN, would seem to be a useful for modeling the most of water resources issues. The ANN are efficiency applicated in river flow prediction, in the rainfall-runoff relationship, in rainfall estimation, in various groundwater problems and many other applications (Cigizoglu, 2000) ANN also was applied in groundwater problems as simulating pumping index for hydraulic conductivity realization to remediate groundwater under uncertainty, modeling water table depth fluctuations (Rajanayaka et al., 2001) and estimation soil moisture (Jiang et al., 2004).

3.8 Artificial Neural Networks applications in Groundwater Quality Modeling

It is difficult to separate groundwater quality modeling and other hydrology modeling as different sections. Many articles have addressed both these topics to some extent. In recent years, ANN has found a number of applications in the area of water quality modeling. Water quality is influenced by many factors such as flow rate, contaminant load, medium of transport, water levels, initial conditions and other site-specific parameters. The estimation of such variables is often a complex and nonlinear problem, making it suitable for ANN application. There are several instances where ANN has been used to address groundwater quality related issues. For instance,

Sandhu and Finch (1996) used ANN to relate flow conditions and gate positions in the Sacramento San Joaquin Delta to salinity levels in the interior and along the boundary of the delta. ANN were further used to estimate flow in the Sacramento River to meet salinity standards. Sandhu and Finch (1996) found simulation models too slow and the commonly used statistical models to be inadequate, and they concluded that neural networks would be suitable for this application. Historical flows from various gauging stations and gate positions served as inputs to the network. Total dissolved solids concentrations data for 20 years were available as network output. In their preliminary work, the authors used the data from 1980–1990 for calibration, and the data from 1971–1980 for validation. Future plans include more rigorous testing of neural networks for salinity predictions (Sandhu and Finch, 1996).

Rogers and Dowla (1992) employed an ANN, which was trained by a solute transport model, to perform optimization studies in ground-water remediation. They investigated hypothetical scenarios of one or several contaminant plumes moving through a groundwater region with a number of pumping wells. The wells could be on or off. The goal of remediation was to keep contamination concentration in some specified monitoring wells lower than the regulatory limit. The optimization arises in trying to minimize the total volume of pumping. A multilayer feed forward ANN was trained using the back-propagation training algorithm (Rogers and Dowla, 1994).

Morshed and Kaluarachchi (1998) used an ANN to estimate the saturated hydraulic conductivity and the grain size distribution parameter for application in the problem of free product recovery. They also concluded that the search process in the parameter space could be accelerated when the ANN was guided by a genetic algorithm (Morshed and Kaluarachchi, 1998).

Ray and Klindworth (1996) lay a blueprint for addressing the problem of agriculture chemical assessment in the rural private wells in Illinois using neural networks. They envisioned that important inputs would be depth to the aquifer material, well depth, land topography in the vicinity of the well, distance of potential contaminant sources from the well, and timing of precipitation with respect to pesticide application. They also discussed how data would be collected for such an application and commented about the utility of ANNs in such applications (Ray and Klindworth, 1996).

The use of ANN in groundwater quality modeling at Gaza Strip doesn't found in large scale, Till now, only one researcher used it. Al Mahalawi used Artificial Neural Network in Modeling Groundwater Nitrate Concentration of the Gaza Strip (Mahalawi, 2007). This research - Groundwater Salinity Modeling Using Artificial Neural Networks Gaza Strip case study - might be considered as one of the few contributions in quantitatively modeling of the relation between groundwater salinity and the hydrological variables in spatial scale using ANN.

Chapter (4)
Study Area Description

4.1 Location and Population

The Gaza Strip is a narrow strip of land on the Mediterranean coast. It is situated in the southeastern coast of Palestine with longitudes of 34:21:38 E and Latitudes of 31:29:45 N. The area is bounded by the Mediterranean in the west, the 1948 cease-fire line in the north and east and by Egypt in the south The total area of the Gaza Strip is 365 km^2 with approximately 40 km long and the width varies from 8 km in the north to 14 km in the south (UNEP, 2003). Figure (4.1) showed regional and location map of Gaza Strip.

In 1948, the Gaza Strip had a population of less than 100,000 people. By 2007, approximately 1.4 million Palestinians lived in the Gaza Strip, of whom almost one million were refugees. The current population is estimated to be in excess of 1.5 million, distributed across five Governorates. Gaza City, which is the biggest governorate, has about 400,000 inhabitants (UNEP, 2009). The estimated annual growth rate in Gaza Strip in 2007 is 3.8%. Table (4.1) presented the estimates of the population number and growth rate in Gaza Strip from 1997 to 2015 (PCBS, 2007).

Table (4.1) : The revised estimates of the population projection in Gaza Strip (PCBS, 2007)

Year	Mid Year Population	Growth Rate (%)	Year	Mid Year Population	Growth Rate (%)
1997	995,522	4.3	2007	1,499,369	3.8
1998	1,039,528	4.4	2008	1,556,201	3.7
1999	1,086,970	4.5	2009	1,614,018	3.6
2000	1,137,990	4.6	2010	1,672,785	3.5
2001	1,188,130	4.0	2011	1,732,438	3.5
2002	1,236,372	4.0	2012	1,792,895	3.4
2003	1,286,109	3.9	2013	1,854,353	3.3
2004	1,337,236	3.9	2014	1,917,019	3.3
2005	1,389,789	3.8	2015	1,980,825	3.2
2006	1,443,814	3.8			

4.2 Topography

Gaza Strip is a coastal foreshore plain gradually sloping westward toward the sea allowing for surface run-off to rein filtrates the soil. A sandy beach stretches all along the coast, bound in the east by a ridge of sand dunes known as Kurkar ridges (Bruins et al., 1991).The altitude of the Gaza Strip land surface ranges between zero meters at the shore line to about 90 meters above mean sea level in some places, as shown in Figure (4.2).

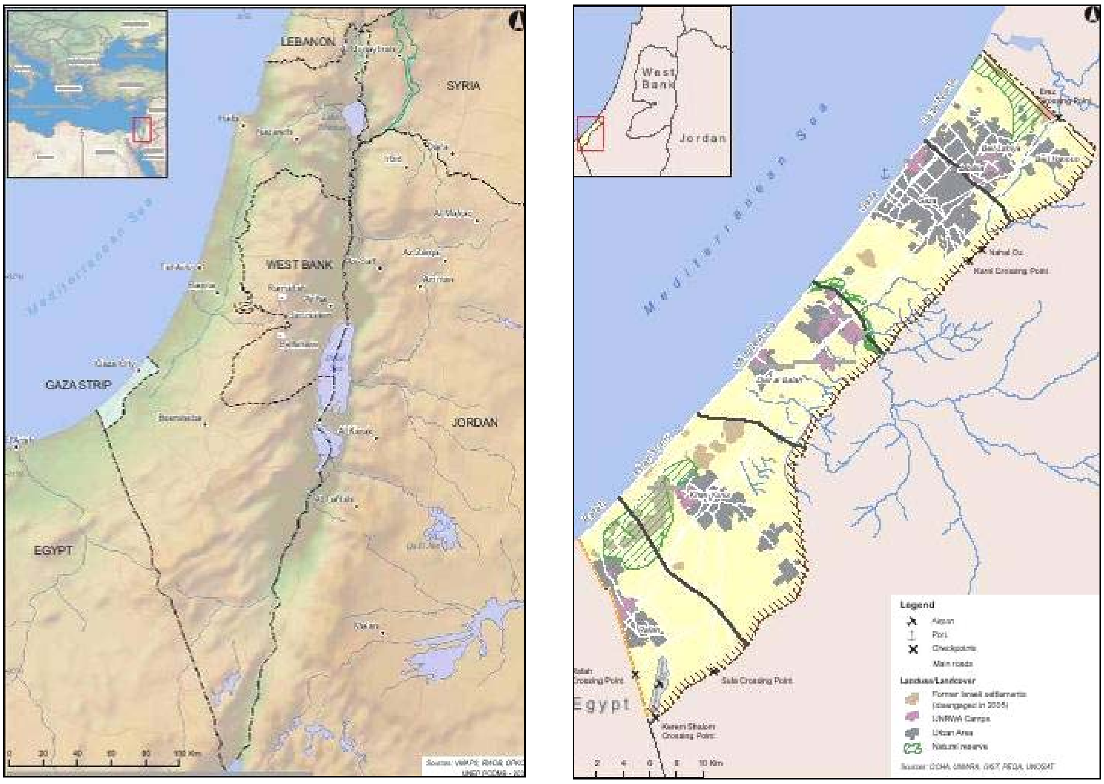

Figure (4.1): Regional and location map of Gaza Strip (UNEP, 2009)

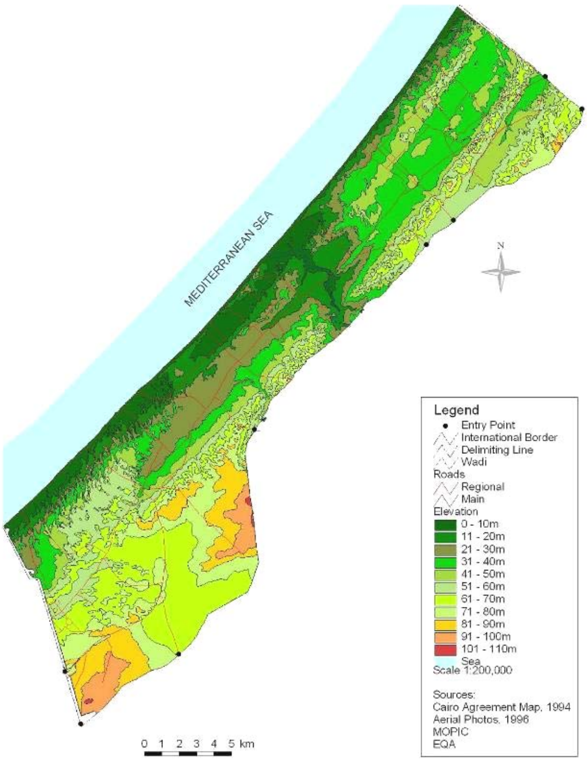

Figure (4.2): Topographical map of Gaza Strip (MOPIC, 1997)

4.3 Climate and Rainfall

4.3.1 Climate

Gaza Strip area has a characteristically semi-arid mediterranean sea climate. It is located in transitional zone between a temperate mediterranean climate to the west and north, and the arid Negev and Sinai deserts to the east and south and there are two distinct seasons; cool and relatively wet season (October-March), and hot and dry season (April-September). The average daily temperature in the Gaza Strip ranges from 26°C in summer to 12°C in winter with the average daily maximum temperature range from 29°C to17°C ,and the minimum temperature range from 21°C to 9°C, in the summer and winter respectively. The daily relative humidity of this coastal area ranges from 65% to 85%in summer and from 60% to 80% in winter in the day time and at night respectively (GMS, 2005).

The wind velocity with northwest direction at 2 meter above the surface in the summer is about 1.5 m s^{-1} , which is less than that's during winter months where velocity reaches values of 2.8 m s^{-1} (Haeyer, 2000).

The mean daily evaporation is variable during the year, where it ranges from about 2.1 mm/d, in December to 6.3 mm/d in July. The high potential evaporation is primarily related to high solar radiation incident over the strip at 190 kg-calories/cm^2/year (U.S. National academy of Sciences, 1999). The generally cloudless summer months (April through September) and consequently open water evaporation is high in the summer, accounting for as much as 70 % of the annual total evaporation (GMS, 2005).

4.3.2 Rainfall

Rainfall is one of the most important parts of the water resource. It is an essential component of scientific investigation of the hydrologic cycle. The pattern, the amount beside the intensity of rainfall are the most important factors that directly affect to groundwater balance and replenishment in the Gaza Strip, rainfall is the main source of groundwater recharge area. The area is located in the semi-arid zone and there is no source of recharge other than rainfall therefore a detailed knowledge of rainfall regime and its distribution is a perquisite for water resources planning and management in Gaza Strip.

In Gaza Strip there are 12 manual rainfall stations distributed through different governorates as shown in Figure (4.3). Data from these stations are collected on a daily basis, these stations are operated by ministry of agriculture and data obtained from these stations are entered manually in Palestinian water authority database. The rainfall occurs in the winter period, which is between Octobers to March; and the mean annual rainfall varies 350-400 mm/year. The period for June to September is dry with no rainfall therefore the rainfall is the main source of almost all water in this area (GMS, 2005).

In the 2006-2007 season, average rainfall depth over Gaza Strip area is estimated about 364.7 mm with total amount 133.1 MCM received through 46 rainy days. Despite of the small area of Gaza Strip (365km^2), the level of rainfall varies significantly from one area to the next with an average seasonal rainfall of 521.9 mm in north area (north governorate), to 225 mm in the southern area (Rafah Governorate) as shown in Figure (4.3) (PWA, 2007).

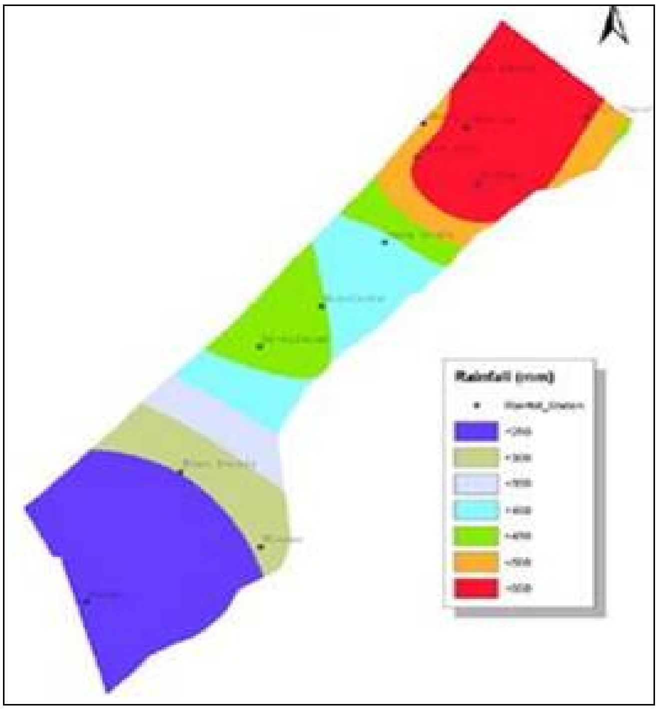

Figure (4.3): The rainfall depth in Gaza Strip for 2006-2007 season (PWA, 2007)

4.4 Land Use

Land is one of the main scar natural resources in the Gaza Strip. Land is one of the primary natural resources in the Gaza Strip so land ownership is the major factors that play a role in any development plan. The major part of the Gaza Strip land is owned by the private sector. Figure (4.4) presented land use in Gaza Strip and Figure (4.5) presented the proposed future land use distribution in 2015.

The distribution of the proposed land use within the Gaza Strip per type of use for the year 2004 is illustrated in Table (4.2) derived from the study carried out by Ministry of Local Governorates (MOLG). Agriculture and assisting agriculture lands occupies about 47.5% of the land surface and the residential area represented 24%, public building 2.1%, where the main and secondary roads represented about 7.64% of the land surface.

Table (4.2): Proposed land use distribution in Gaza Strip in 2004 (MOLG, 2004)

Type of Use	**Area (km^2)**	**Area %**
Main and Secondary Roads	27.875	7.64 %
Public Building	7.675	2.10 %
Residential Areas	87.745	24.04 %
Industrial Area	12.445	3.41 %
Gaza Airport	15.000	0.41 %
Agricultural Area	167.675	45.94 %
Assisting Agricultural Area	5.595	1.81 %
Open and Green Areas	8.100	2.22 %
Reserved Areas for Future Plans	25.450	6.97 %
Others Area	19.940	5.46 %
Total Area	**365**	**100 %**

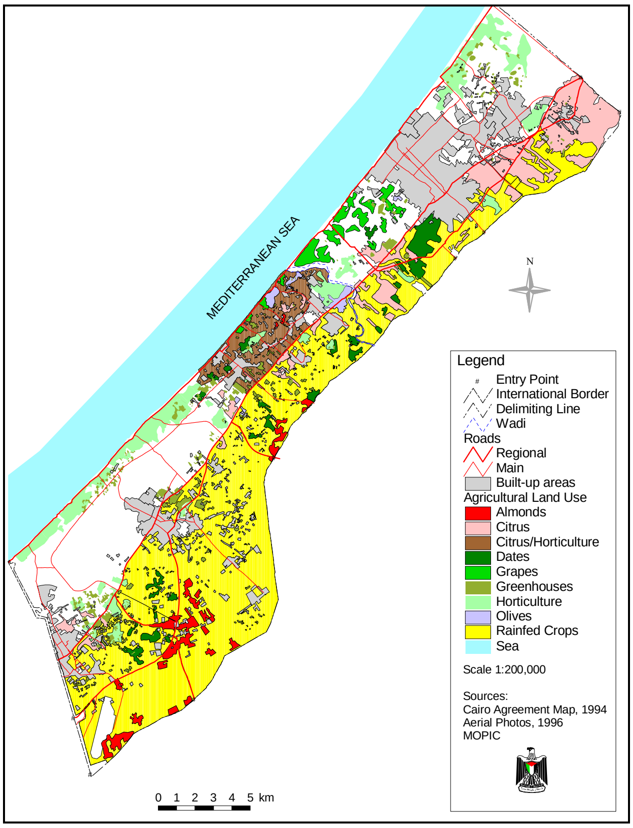

Figure (4.4): Land use in Gaza Strip (MOPIC, 1998)

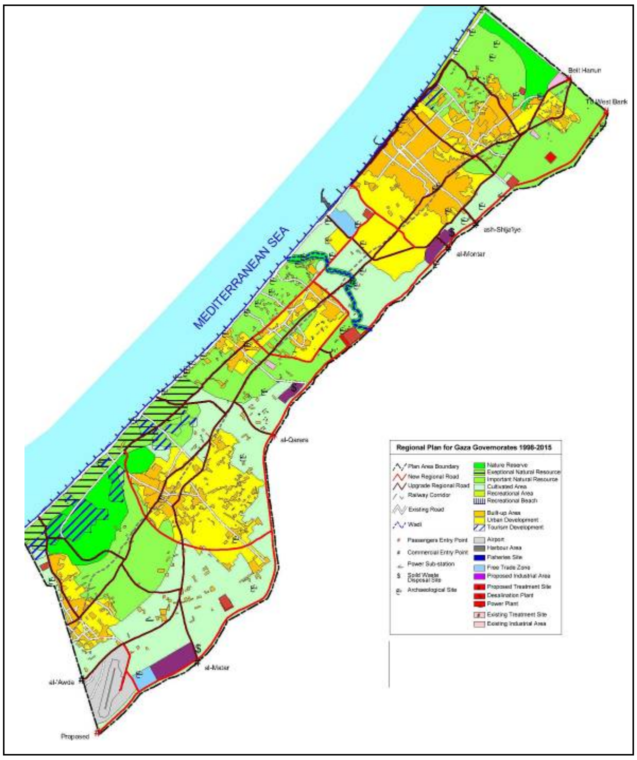

Figure (4.5): The proposed future land use distribution in 2015 (MWGP, 2001)

4.5 Geology

The Gaza Strip is a shore plain gradually sloping to the west. It is underlain by a series of geological formations from the Mesozoic to the Quaternary. The main formations known were composed in the last two system periods, Tertiary formation called “Saqiya formation” of about 1200-meter thickness, and the Quaternary deposits in the Gaza Strip are of about 160 meters thickness and cover Saqiya formation (Mortaja, 1998). Table (4.5) summarizes the geological history of the Gaza Strip, where Figure (4.6) illustrates a geological cross-section in the Gaza Strip.

Table (4.3): Geology and geological history of the Gaza Strip (Palestinian Environmental Protection Authority, 1994) and (Hamdan, 1999)

Era	**System**	**Period**	**Series**	**Age million years**	**Formation**	**Environment of Deposition**	**Lithology**	**Max. Thickness (m)**	**Water Bearing Character**
Cenozoic	**Quaternary**		Holocene	0.01	Alluvial	Terrestrial	Sand, loess, calcareous silt and gravel	25	Locally phreatic aquifer
			Pleistocene	1.8	Continental Kurkar	Aeolian Fluvial		100	Main aquifer
					Marine Kurkar	Near Shore		100	Main aquifer
	Tertiary	**Neogene**	Pliocene	5	Conglomerate	Near Shore	Conglomerate	20	Base of the coastal Zone aquifer
				12	Saqiya	Shallow marine	Clay , Marl, Shale	1000	Aquiclude
			Miocene	22.5		Marine	Marl, Limestone, Sandstone and Chalk	500	Aquiclude alternating permeable layers with saline water
Mesozoic									
Paleozoic									
Precambrian									

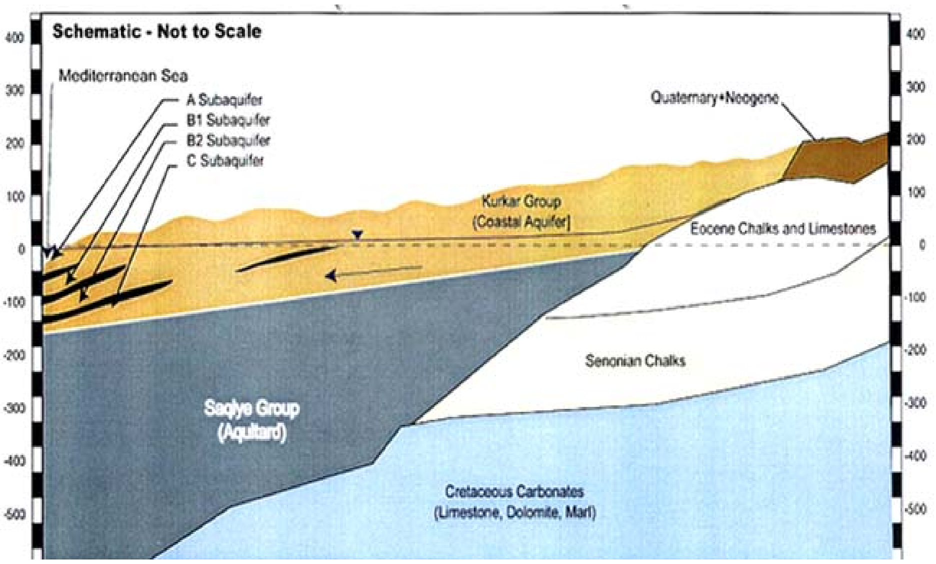

Figure (4.6): A geological sross-section in the Gaza Strip. (Metcalf and Eddy, 2000)

The geological formations deposited in the area are described as follows:

4.5.1 Tertiary Formation

The tertiary formations are composed mainly of Saqiya formation, which consist of clay, Marl and Shale, and overlies the limestone layer beneath. (Hamdan, 1999).The thickness of this formation is about 1200 m at the shoreline, and it descends down rapidly at the east. According to oil exploitation logs, it is found that there are other Tertiary formations such as Chalks, limestone, and sandstonge at depths of 2000 m.

4.5.2 Quaternary Formation

The quaternary deposits have a thickness of about 160 m and covering the Pliocene Saqiya formation. Overlying Pleistocene deposits "Lower Quaternary ", consists of :

4.5.2.1 Marine Kurkar Formation

It is composed of shell fragments and quartz sands with calcareous cement. The thickness varies between 10 to 100 meters on the coast.

4.5.2.2 Continental Kurkar Formation

It is composed of red loamy sand beds (Hamra). The maximum thickness is about 100 meters with often-calcareous cement (PEPA, 1994).

4.5.2.3 Quaternary Deposits

These deposits are found at the top of the Pleistocene formation with a thickness up to 25 m. It can be divided into the following different types:

1. **Sand Dunes**

   Sandy soil is found in the dunes area along the southern seashore, in a width of 2-3 km. The total area of the sandy covers about 70 km^2. The sand dunes are 30-50 m above sea level. Lucite soil is widely spread in the middle of Gaza. This soil is a mixture of sand and loam (Palestinian Environmental protection Authority, 1994).

The thickness of these dunes is about 15 m. These dunes originate partly from Nile river sediments. It extends along the shoreline, with small width in the south, increasing northward up to 3 km.

2. Sand Loess and Gravel Beds.

It has a small thickness of about 10 m, and it is considered as the main formation of Wadi Gaza.

3. Alluvial Deposits.

These formations have a thickness of 25 m and spreading around the Wadi Gaza.

4. Beach Formation

It composed of relatively thin layer of sand with shell fragments. It is mainly unconsolidated, however; in some places, it is cemented due to deposition of calcium carbonate.

4.6 Soil Condition

4.6.1 Subsoil Formation

The deposits formed in the Pleistocene and Holocene ages are classified as subsoil formations and soil respectively. The subsoil formations from the Pleistocene age are distinguished in two categories that are:

4.6.1.1 Kurkar

Kurkar formations results from the continuous deposition of sand through the Pleistocene age in a sedimentary basin, which extends beyond the border of the coastal region. The sand was deposited as Aeolian dunes that consolidated later by litho static pressure and precipitation. Cemented sandstone are present near the surface, they form distinctive topographic ridges with vertical relief up to 60 meter. These Kurkar ridges, from which the coastal aquifer has obtained its name, typically extend in NE-SW direction. Hamdan (1999) emphasized that this formation is the water-bearing layer that allows significant amounts of water to go through. The hydraulic conductivity (the rate at which the formation allows water to go through) of Kurkar depends on the type of the cement (clay mineral, calcium carbonate) (Hamdan,1999).

4.6.1.2 Hamra

Hamra and Kurkar are found in consecutive stratification and formed in the Pleistocene and Holocene series of the Quaternary system. Hamra and Kurkar interchange each other on the outcrops at the ground surface of the Gaza Strip. Hamra formation is a mix of clay, silt and fine grains that are covered by iron oxides with red color. The formation is free of lime and founded in beds at different depths of about one meter thickness. Besides, it can be found in fragmented small layers.

4.6.2 Soil Formation

Soil is the surface layer that covers the rock formation; it is affected by the parent rock and the local climate. It contains a mixture of organic and inorganic constituents, water and air.

As shown in Figure (4.7) soils classification based on soil texture (MOPIC, 1997). Another classification considered the outward properties and soil physical properties in various depths (30 cm, 60 cm, 90 cm, 100 cm) (Goris and Samain, 2001).

The classification and the characteristics of different soil types of Gaza Strip are summarized in Table (4.4).

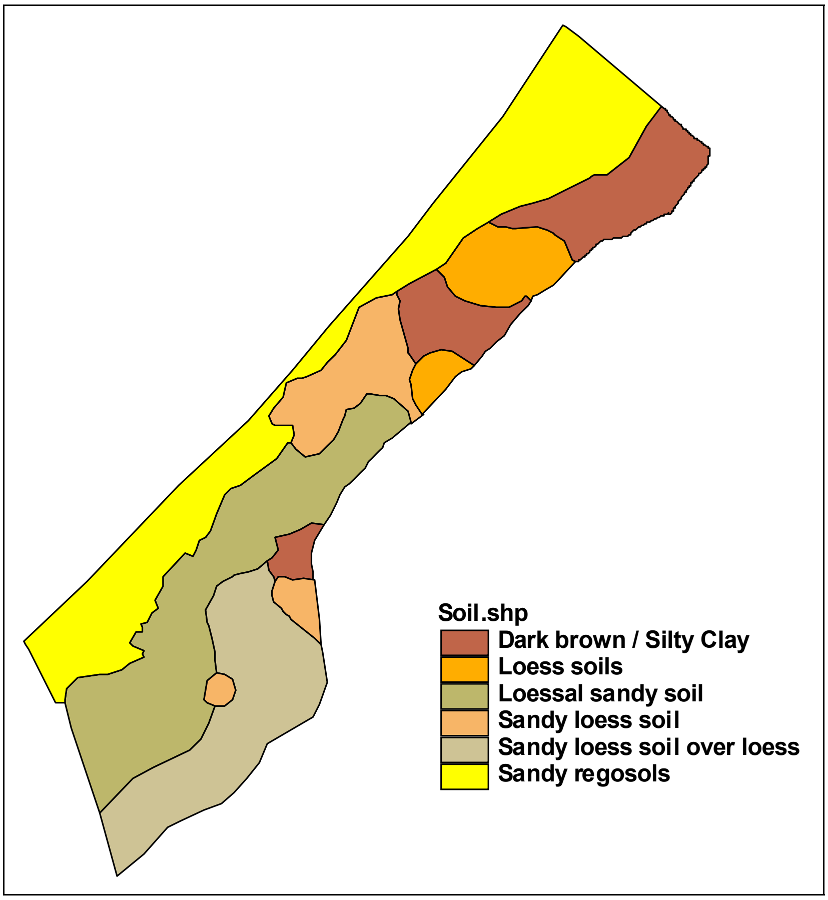

Figure (4.7): Soil Classifications in Gaza Strip (MOPIC, 1997)

Table (4.4): Classification & characteristics of different soil types in Gaza Strip. Adopted from (MOPIC, 1997; Goris and Samain, 2001)

Local Classification	Location	Description	Texture
Loess soil	Between the Gaza city and the Wadi Gaza	Loess soils sedimented in Pleistocene until Holocene Series. The grain size of loess fluctuates from 0.002 to 0.068 mm. Loess has been transported by winds and sedimented in loose form in the upper part, and in hard form in the lower part of the layers. They are brownish yellow-colored often with accumulation of lime concretions in the subsoil and containing 8 – 12 % calcium carbonate.	Sandy loam (6% clay, silt 34% , sand 58%)

Dark brown /reddish brown	Beit Hanoun and Wadi Gaza	These alluvial soils are Usually dark brown to reddish in colour, with a well-developed structure. At some depth, lime concretions can be found. The calcium carbonate content can be around 15–20%	Sandy clay loam (25% clay, 13% silt, 62% sand)
Sandy loess soil	Deir el Balah and Abssan	This is a transitional soil, characterized by a rather uniform, lighter texture. Apparently, windblown sands have been mixed with loessial deposits.	Sandy clay loam (23% clay, 21% silt, 56% sand)
Loessial sandy soil	It is found in the central and southern part of the strip	Forms a transitional zone between the sandy soil and the loess soil, usually with a calcareous loamy sandy texture and a deep uniform pale brown soil profile.	The top layer is sandy loam (14% clay, 20% silt, 66% sand). The lower profile is loam (21% clay, 30% silt, 49% sand)
Sandy loess soil over loess	It is found east of Rafah and Khan Younis	It is loess or loessial soils which have been covered by a 20 to 50 cm thick layer of sand dune	Sandy loam (17.5% clay, 16.5% silt, 66% sand)
Sandy regosol	It is found a long the coast of Gaza Strip	Soil without a marked profile. Texture in the top meters is usually uniform and consists of medium to coarse quartz sand with a very low water holding capacity. The soils are moderately calcareous, very low matter and chemically poor, but physically suitable for intensive horticulture in greenhouses. In the deeper subsurface occasionally loam or clay loam layers of alluvial origin can be found	Top layer is loamy sand (9% clay, 4% silt, 87% sand). Deeper profile is sand (7.5% clay, 0% silt, 92.5% sand)

4.7 Hydrology

Precipitation falling on land is either returned directly to the atmosphere by evaporation, flows along the land surface to become surface water or percolate into the round. Water that infiltrates into the ground is either drawn into plants and returned to the atmosphere by transpiration or continues infiltrating and becoming groundwater.

4.7.1 Surface Water Hydrology

The surface water system in the study area is Wadi Gaza. Wadi Gaza that located at the southern boundary of study area is the bigger in Gaza Strip. It runs in the central part of the Gaza Strip and discharge into the Mediterranean Sea Wadi Gaza length is about 9 km in Gaza and it extends into the armistice border for about 95 km where it collects the water from a big catchment area (3600 km^2) from the Hebron Mountains and the Northern Negeve. This main stream was diverted by the Israelis to an adjacent area where it's been stopped their and collected at basins located 6km east of Gaza (MWCP, 2001).

Wadis are ephemeral streams, characterized by short duration floods that occur after heavy rainfall, while most of the time they are completely dry. Freshwater flows into them in the winter season. Israel has retained and changed the course of the two Wadis and they become dry since the early seventies, this means that fresh surface water resources are negligible.

4.7.2 Groundwater Hydrology

The coastal aquifer underlies the Coastal Plain of Palestine and runs parallel to the Mediterranean Sea coast. The coastal aquifer is an underground phreatic reservoir varies in width from 7 km in the north to 20 km in the south; its thickness decreases eastwards from 200 m near the coastline to a few meters in the eastern margins (PWA, 2000a). The aquifer (the Kurkar Group of Pleistocene age) consists of sand, sandstone, and silt interbedded with marine clays, and it overlies the impervious marine clays of upper Eocene to Pliocene age (the Saqiye Group). The aquifer is basically phreatic, but clay layers divide it vertically into several subaquifers. The hydraulic connection between groundwater in the different subaquifers and the sea is not well understood. While Bear and Kapuler (1981) considered that all subaquifers are connected to the sea, Kolton (1988) argued that the lower subaquifers are disconnected (Oren, et al., 2004). In the central and eastern areas the aquifer is uniform and phreatic. The calcareous sandstone (arenites or "kurkar") is composed of several minerals: quartz, feldspar, calcite, aragonite, and iron oxides (Vengosh, et al., 1996).

4.7.2.l Hydrostratigraphy

In the study area, the coastal plain aquifer contains many diverse hydraulic and hydrologic units and thus, several water-producing zones. The layered stratigraphy of the Kurkar Group subdivides the coastal aquifer from top to bottom into four separate sub-aquifers near the coast A, Bl, B2 and C as shown in Figure (4.6) . This subdivision is conditioned by impervious to semi-impervious interlayers alternating with predominantly permeable calcareous sandstones, and persists along the coastal strip but dissipates 4-6 km east of the shoreline. East of the third ridge the Kurkar Group sequence is randomly subdivided by occasional occurrence of impervious to semi-impervious layers and the coastal aquifer can be regarded as one hydrogeological unit. The upper subaquifer "A is unconfined, whereas subaquifers "Bl, B2, and C become increasingly confined towards the sea (Al-Jamal and Yaqubi, 2000).

4.7.2.1.l Kurkar Group

- **Sub-aquifer A:**

Sub-aquifer (A) occurs in the uppermost and westernmost part of the sequence extends from the shoreline to the east up to 2 km. It is mainly composed of variously cemented concretionary calcareous sandstone mixed and interlayered with loose sand, of both continental and littoral origin. This aquifer is bounded from the top by the water table and at the bottom partly bounded by the first aquitard of silty clay. In the study area, it is 25m thick in the east to about 60-m in the west. This aquifer unit overlies continental-estuarine clay or loam extending eastwards and upwards, reaches in thickness to 15 m. However, the clay-rich base layer of sub-aquifer A is not always continuous and therefore, the hydrogeological and hydro stratigraphical separation between sub-aquifer A and underlying subaquifer B does not always exist or can be clearly identified. Sub-aquifer A may contain thin interlayers of clay, sandy clay and silty clay, which act as aquitards.

- **Sub-aquifer B1:**

Based on Israel studies of Ecker, 1999 sub-aquifer B1 is mainly from Kurkar and micro-conglomerate deposited in a more littoral environment, the cementation of which is harder than in the overlying sub-aquifer A and having a lower proportion of loose sand. The base of this sub-aquifer is formed by marine to lagoonal-estuarine clays. Further eastwards, these base layers turn into continental clays and loarns and extend 6-7 km east of the shoreline.

- **Sub-aquifer B2**

The calcareous sandstones of this unit are predominantly products of a high-energy littoral depositional environment, such as conglomerates and beach rock overlying a marine clay horizon. Based on Israel studies sub-aquifer B2 is 20-40-m thick. Near the coastline, sub-aquifer B2 occurs between elevations of (- 120) and (- 150) m below MSL (Zilberbrand et al., 2001).

- **Sub-aquifer C**

Between the shoreline and 3-4 km inland, the lithology of this sub-aquifer is of a marine type, with no indications of shallower facies. It is characterized by interlayering of clay, silt, and silty sand, 10-20-m thick. Generally, the occurrence of calcareous sandstones increases eastwards on account of silty-clayey beds. The hydraulic conductivities of this unit are significantly lower than in the overlying sub-aquifers. Sub-aquifer C overlies impervious layers related to top of the Saqiye Group. Their occurrence is usually marked by thin streaks of chalky and marly sandstone, yellowish chalky marl, and clays. The top of the Saqiye occurs at elevations of -150 to -160 m below MSL, close to the shoreline (Zilberbrand et al., 2001).

4.7.2.1.2 The Saqiye Group

The Pleistocene Coastal Plain aquifer system (the Kurkar Group) overlies a very thick complex of shales and marls related to the Plio-Pleistocene Saqiye Group that wedges out gradually eastwards. In the study area its maximum depth reaches 1900 m near the coastline, wedging out in the eastern parts of the Coastal Plain. The top of the Saqiye Group dips 1-2% westwards (Zilberbrand et al., 2001).

4.7.3 Aquifer Hydraulic Properties

4.7.3.1 Transmissivity

From results of aquifer tests carried out in Gaza Strip, transmissivity values range between 700 and 5000 square meters per day (m^2/d).corresponding values of hydraulic conductivity K are mostly within a range of 20-80 meters per day (m/d). Most of the wells that have been tested are municipal wells screened across more than one sub-aquifer. Hence, little is known about any differences in hydraulic properties between sub-aquifer (PWA, 2000b).

4.7.3.2 Effective Porosity:

Groundwater velocity is inversely proportional to effective porosity. Thus, a reduction in effective porosity implies in an increased velocity and hence faster migration of a particular contaminate. The base case calibration value is 25%.three sensitivity runs were carried out 15%, 20%, and 30% (PWA, 2000b).

4.7.3.3 Specific Yield and Specific Storativity

Specific yield values are estimated to be about 15-30 percent while specific storativity is about 10^{-4} from tests conducted in Gaza. Concerning the specific yield values is asking only about the porosity so the porosity values are consistent with the specific yield values (effective porosity 25%) for the sand and gravel (PWA, 2000b). Table (4.5) represented hydraulic properties in Gaza Strip subaquifers

Table (4.5): Aquifer hydraulic properties (PWA, 2000b)

Stratigraphic Unit	**Horizontal Hydraulic Conductivity (m/d)**	**Vertical Hydraulic Conductivity (m/d)**	**Specific Yield**	**Specific Storativity' (m^{-1})**
Subaquifer A	30.0	3.00	0.25	0.1 E-04
Subaquifer B1	30.0	3.00	0.25	0.1 E-04
Subaquifer B2	30.0	3.00	0.25	0.lE-04
Subaquifer C	30.0	3.00	0.25	0.lE-04
Coastal Clays / Aquitards	0.20	0.20	0.10	0.lE-04
Undifferentiated Aquifer East of Coastal Clays	5.0 - 30.0	0.5 - 3.0	0.25	0.lE-04

4.7.4 Groundwater Balance

In order to analyze the water balance in the Gaza Strip, it is necessary to compare water supply with water demand (Assaf, 2001). It should be noted that, the Gaza coastal aquifer is a dynamic system with continuously change inflow and outflow. The present net aquifer balance is negative, that is a water deficit. Under defined average climate condition and total abstraction and return flows; the net deficit range between 18-26 Mm^3/yr. as shown in Table (4.6).

In the year 2020, there will be 2 million inhabitants, double the current population, and the water demand could easily double from the current 170 Mm^3/yr. to 216 Mm^3/yr., which makes it necessary to generate and obtain additional water supplies in order to cover these alarming shortages (Adopted from Metcalf and Eddy, 2000).

Table (4.6): Estimated water balance of Gaza Strip (Adopted from Metcalf and Eddy, 2007)

Inflows (Mm^3/yr.)			**Outflows (Mm^3/yr.)**		
	Min.	**Max.**		**Min.**	**Max.**
Rainfall recharge	40.0	45.0	Municipal abstraction	80.0	85.0
Lateral inflow from Israel	18.0	30.0	Agriculture abstraction	80.0	100.0
Lateral inflow from Egypt	2.0	5.0	Mekorot abstraction	5.0	8.0

Saltwater intrusion	10.0	15.0	Discharge to the sea	10.0	15.0
Water system leaks	10.0	15.0			
Wastewater return flow	10.5	10.5			
Irrigation return flow	20.0	25.0			
Loss of aquifer storage	2.0	3.0			
Other recharge	3.5	3.5			
Total	**116**	**152**		**175**	**208**
Net balance	**59**	**56**			

Chapter (5)

Methodology

5.1 Introduction

This chapter discusses the utilized methodology in this research. Many techniques, approaches and tools were used to achieve the objectives of this research.

In order to model the groundwater salinity in Gaza strip using ANN it is necessary to gather data for training purposes. The training data must include a number of cases, each containing values for input and output variables. The first decisions needed are: which are variables to use, and how many (and which) cases to gather? The choice of variables (at least initially) is guided by intuition. Understanding and expertise in the problem domain and conditions give initially idea of which input variables are likely to be influential. Once in ANN, variables can be select and deselect, ANN can also experimentally determine useful variables. As a first pass, any variables which could have an influence on groundwater salinity should be included on initial studies.

Initially, it is assumed that the groundwater salinity (represented by chloride concentration mg/l) may be affected by some variables as: recharge rate (R), abstraction (Q), abstraction average rate (Qr), life time (Lt), groundwater level (Wl), aquifer thickness (Th), depth from surface to well screen (Dw), and distance from sea shore line (Ds). These variables were chosen depending on the literature review in Chapter two.

5.2 Data Collection and Preparation

The required data were extracted mainly from the domestic wells in Gaza Strip because it usually have quality test twice a year in February and October periodically. The quality test includes the chloride concentration test which gives us a great chance to monitor groundwater salinity in Gaza Strip and it's changes two times per year. The assumed variables will be gathered, studied, validated and rearranged to create training data matrix which should contain many hundreds of cases each containing values for input variables and output.

It is noted that the raw data available with institutions at Gaza Strip may have some errors which mainly associated with human error and many necessary data had been lost or not found. This confuse the work and restrict the ability to collect large quantity of data which have negative effect on the performance of the new constructed model.

In this research, it is necessary to deal with regular time series data to construct data training matrix so many sources of data have been neglected because of the deficiency of complete required data. Since that the detailed abstraction records have not been obtained for years prior to 1996, the period of model which include the modeling and calibration starts from 1997 to 2006. The methodology of gathering and preparation each variable is discussed in the following sections.

5.2.1 Water Wells in Study Area

There are an estimated 4000 wells within the Gaza Strip, almost all of these wells are privately owned and used for agricultural purposes. Approximately 100 wells are owned and operated by municipalities and are used for domestic supply. (PWA, 2000).

In this research, data were extracted from 56 wells, most of them are municipal wells and they almost cover the total area of Gaza Strip. The choice of these wells depends only on the availability of required data. The primary data of study wells include the locations represented by X ,Y and Z local coordinate, governorate , well type and the year of operation. These data of study wells are presented in Table (5.1), Figures (5.1) and (5.2). The general information of study wells of all study wells from 1997 to 2006 are represented in Annex 1.

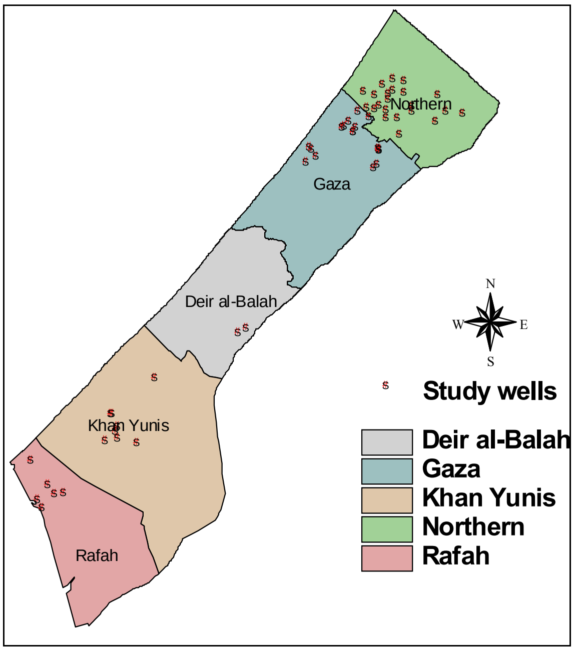

Figure (5.1): Study wells location in Gaza Strip

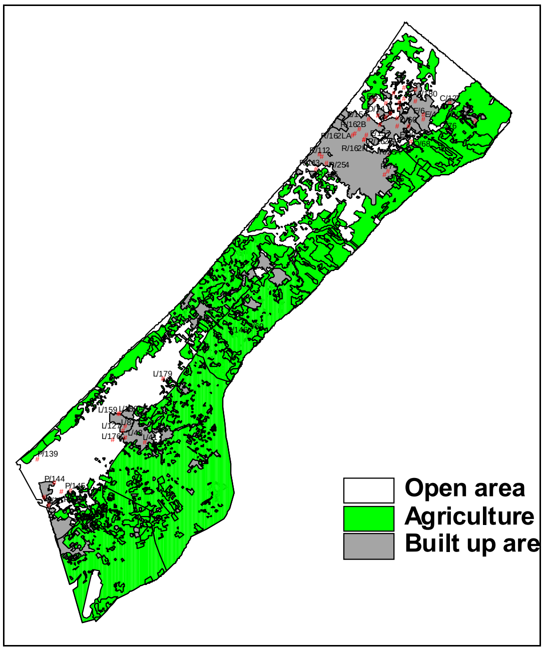

Figure (5.2): Study wells and land use in Gaza Strip

Table (5.1): The general information of study wells

Well ID	Ag No	X_PWA	Y_PWA	Z_PWA	Gov.	Well type	Year of operation
10710104	D/67	101715.90	107217.90	22.90	North	Municipal	1987
10710214	A/180	102458.90	107032.70	24.10	North	Municipal	1983
10610017	D/73	101036.50	106827.40	37.20	North	Municipal	1996
10610120	D/72	101739.30	106462.40	21.60	North	Municipal	1998
10609906	E/61	99737.40	106339.30	44.80	North	Municipal	1974
10610215	A/185	102530.00	106252.30	40.60	North	Municipal	1987
10610119	D/71	101458.00	106192.90	28.00	North	Municipal	1998
10610403	C/127	104777.60	106153.90	57.20	North	Municipal	1987
10610015	D/74	100503.70	106104.10	40.00	North	Municipal	1997
10610016	D/70	101439.90	105833.20	24.90	North	Municipal	1996

5.2.2 Chloride Concentration Data

Groundwater quality in Gaza Strip is monitored by different institutions as Ministry of Health (MOH) and Ministry of Agriculture (MOA). This research concerns with data of MOH because it usually performs quality test twice a year in February and October periodically. MOA do not adhere periodically tests, and so it is impossible to make periodical monitor of chloride concentration and salinity using agriculture wells.

The data of some domestic wells were neglected because of the lost of some necessary required data especially in chloride concentration and abstraction data. Table 5.2 presents chloride concentration of some study wells from 1997 to 2000. Figure (5.3) presented average chloride concentration of pumped Groundwater of Gaza Strip for the year 2007. <u>The chloride concentration of all study wells from 1997 to 2006 are represented in Annex 2.</u>

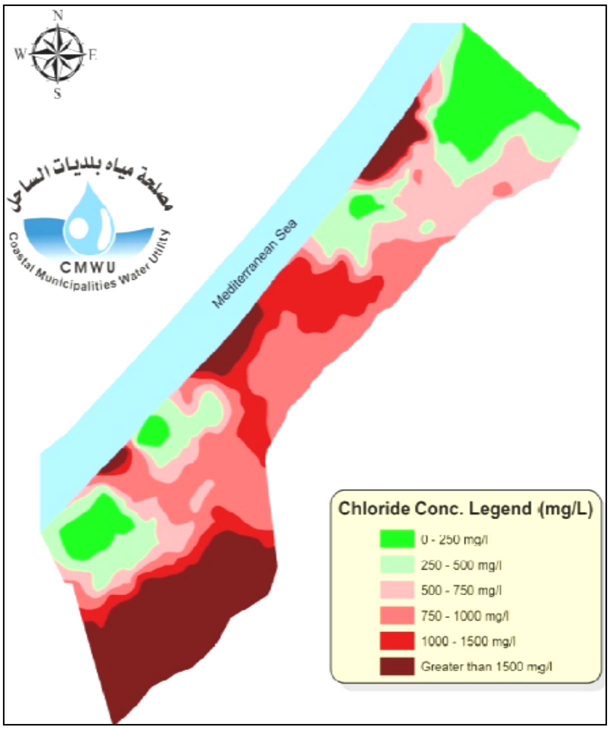

Figure (5.3): Average chloride concentration of pumped groundwater of Gaza Strip for the year 2007 (CMWU, 2007)

Table (5.2): Chloride concentration (mg/l) of some study wells from 1997 to 2000

Ag No	01/04/1997	01/10/1997	01/04/1998	01/10/1998	01/04/1999	01/10/1999	01/04/2000	01/10/2000
D/67	78.0	55.0	56.0	56.0	42.0	NA	42.0	35.3
A/180	35.0	NA	49.0	56.0	49.0	63.0	70.0	77.0
D/73	NA	NA	56.0	63.0	63.0	63.0	63.0	56.0
D/72	NA	NA	NA	71.0	77.0	NA	70.0	63.0
E/61	66.0	145.0	42.0	135.0	182.0	NA	385.0	749.0
A/185	70.0	100.0	77.0	85.0	84.0	77.0	91.3	91.0
D/71	NA	NA	70.0	78.0	74.0	66.0	77.0	70.0
C/127	92.0	100.0	70.0	70.0	77.0	84.0	77.0	77.0
D/74	56.0	65.0	56.0	71.0	77.0	77.0	77.0	77.0
D/70	79.0	NA	70.0	85.0	88.0	NA	91.0	91.0

5.2.3 Recharge Rate

Recharge refers to the entrance of water into soil or porous material through the interstices or pores of a soil or other porous medium. Infiltration is the sole source of soil water to sustain the growth of vegetation and of the groundwater supply of wells, springs, and streams (Schwab et al., 1993).

The capacity of any soil to absorb the rainwater falling continuously at an excessive rate goes on decreasing with time until a minimum rate of infiltration reached. The infiltration rate is a function of time, and has the dimensions of volume per unit of time per unit of area. These units reduce to depth per unit time; it is expressed in (mm/min) (Suresh, 1993).

Major component of recharge in the Gaza coastal aquifer model include :

- Recharge from rainfall.
- Return flows from irrigation.
- Return flow from other sources (water distribution systems, septic systems, and wastewater collection systems, wadi Gaza and infiltration basins) (CAMP, 2000).

5.2.3.1 Factors Influence Infiltration Rate.

The infiltration rate differs from one type of soil to another However, since the increasing urban development, the natural soil was disturbed and covered by impermeable layers such as paved roads or occupied by buildings. This, of course reduced drastically the amount of infiltrated rainfall that replenishes the groundwater. The decrease in infiltrated rainwater appeared as a surface run-off, is lost by either evaporation or diverted to the sea.

The infiltrated water in Gaza Strip goes through the soil in a rate of one to two meters per day in the areas where fine sand is found, and this rate increases in the coarser formation e.g. kurkar. However, the percolation rate decreases, if it encounters a clayey layer in the subsurface. Water goes horizontally above the non-permeable layer until it encounters a disconnection in this layer and travels vertically downward to groundwater reservoir (PWA, 2003).

The National Soil Survey Center in cooperation with (NRCS) and the U.S Agricultural Research Service (USDA) suggested in (1998) that a number of factors, which affect soil infiltration, some of these factors, are follow:

1- Crust

Soils that have many large surface connected pores have higher intake rates than soils that have few such pores. A crust on the soil surface can seal the pores and restrict the entry of water into the soil.

2- Compaction

A compacted zone or an impervious layer close to the surface restricts the entry of water into the soil and tends to result in pounding on the surface.

3- Soil Texture

The type of soil (sandy, silty, and clayey) can control the rate of infiltration. For example, a sandy surface soil normally has a higher infiltration rate than a clayey surface soil. Hamdan (1999) suggested that soil texture is important to identify the vulnerability of the artificial recharge basin to surface sealing, where a thin lamina of fine particles covers the surface of spread basin will decrease the infiltration much more clogging. Goris and Samain (2001) described the texture of five different soils in Gaza strip, while Hamdan (1999) added another sixth one as shown in table (5.3).

Table (5.3): Texture and infiltration Parameters of the Different Soil Types in the Gaza Strip (Goris and Samain, 2001) and (Hamdan, 1999)

Soil type	Clay %	Silt %	Sand %	Soil texture	Initial infiltration rate (f_o) mm/hr	Basic infiltration rate (f_b) mm/hr	soil parameter (k)
Sandy regosol	08.5	01.8	89.8	Sandy	1263.0	401.4	0.24
Sandy loess soil over loess	17.5	16.3	66.2	Sandy loam	357.6	97.2	0.08
Loessial sandy soil	18.0	25.0	57.0	Sandy loam	498.6	145.8	0.08
Dark brown/ reddish brown	25.3	12.8	61.9	Sandy clay loam	1051.2	208.8	0.11
Sandy loess soil	23.2	20.3	56.5	Sandy clay loam	270.6	66.0	0.06
Loess soil	06.0	34.0	58.0	sandy loam	428.1	121.5	0.08

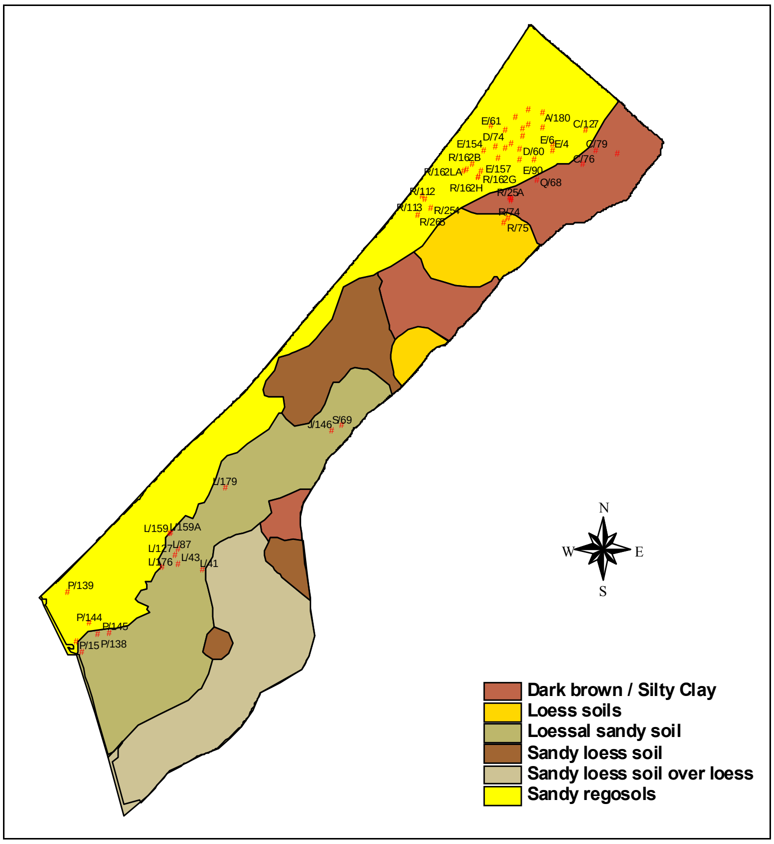

Figure (5.4): The study wells according to soil types of Gaza Strip

4- Organic Matter

An increased amount of plant material, dead or alive, generally assists the process of infiltration. Organic matter increases the entry of water by protecting the soil aggregates from breaking down during the impact of raindrops. Particles broken from aggregates can clog pores, seal the surface, and decrease infiltration during a rainfall event.

5- Pores

Continuous pores that are connected to the surface are excellent conduits for the entry of water into the soil. Discontinuous pores may retard the flow of water because of the entrapment of air bubbles. Organisms such as earthworms increase the amount of pores and assist the process of aggregation that enhances water infiltration.

6- Aggregation and Structure

Soils refer to the arrangements of the soil particles (aggregates) separated by pores and cracks as represented in Figure (5.5). The basic types of aggregate arrangements and its flow rate are shown in Figure (5.6). Soils that have stable strong aggregates as granular or blocky soil structure have a higher infiltration rate than soils that have weak, massive, or plate like structure. Soils that have a smaller structural size have higher infiltration rates than soils that have a larger structural size.

7- Water Content

The content or amount of water in the soil affects the infiltration rate of the soil. The infiltration rate is generally higher when the soil is initially dry and decreases, as the soil becomes wet. Pores and cracks are open in a dry soil, and many of them are filled in by water or swelled when the soil becomes wet. As they become wet, the infiltration rate slows to the rate of permeability for most restrictive layer. Water is stored in the soil within the pore space between the soil particle by forces of attraction acting between the water molecules and the particles of the soil matrix. The forces holding the water to the soil matrix are called matrix forces (Raes, 1999). The amount of water retained and stored in soil after watering and following drainage is important in both plant growth and hydrological studies (Goris and Samain, 2001)

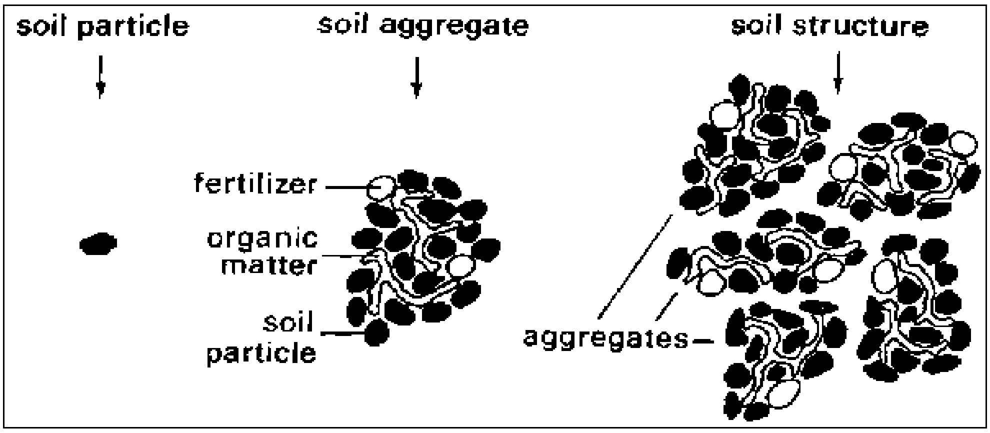

Figure (5.5): The Soil Structure (FAO,1993)

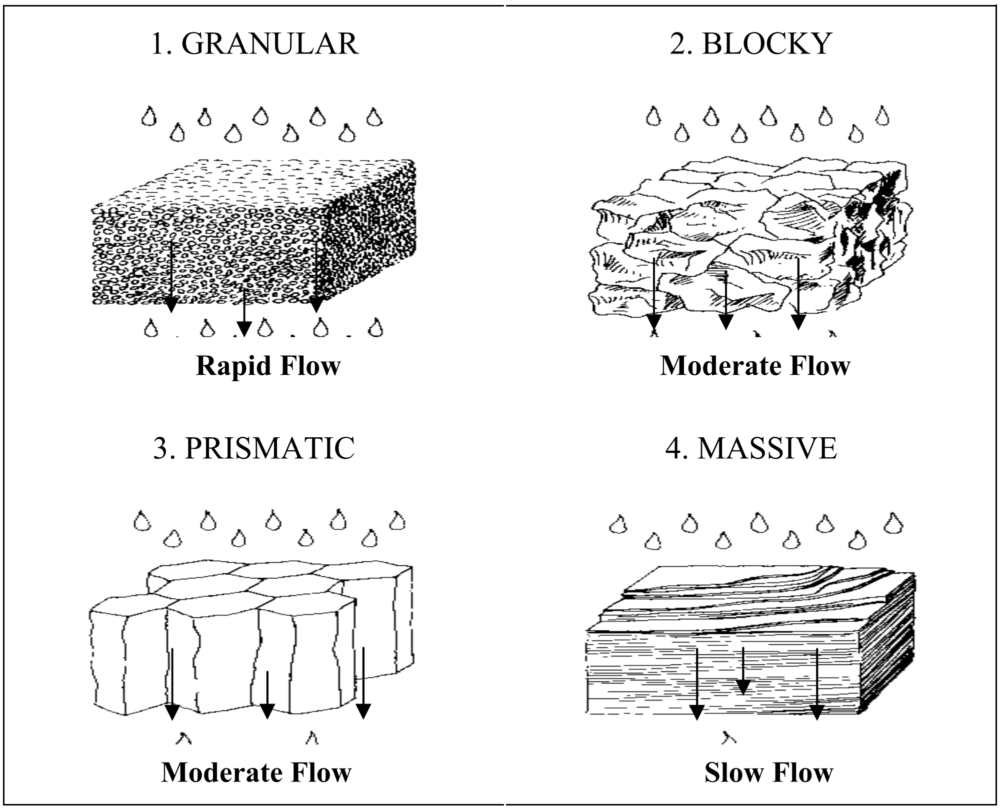

Figure (5.6): The Basic Types of Soil Structures (FAO,1993)

5.2.3.2 Computation Methods of Infiltration

There are numerous techniques available for estimation of water infiltration rate through the soil. These methods may be classified in a various ways according to the way in which water is added, and the measurements are made. In field works, there are various devices for measuring the infiltration rate of water through soils, the most common being the ring infiltrometer.

Empirical methods are usually in the form of simple equations. These equations only provide estimates of cumulative infiltration and infiltration rates, and do not provide information regarding water content distribution. Most are derived based on a constant water content being available at the surface. (Parlange and Haverkamp, 1989).

The study of all methods is not the scope of this study; put it is good to study the most familiar method, which can be applicable to the soils type of Gaza Strip, whish is Horton's equation. Horton's Equation (1939) is an empirical relation that assumes infiltration begins at some rate f_o and exponentially decreases until it reaches a constant rate f_b (Chow, et al.,1988).

The infiltration rate is expressed as:

$$f = f_b + (f_o - f_b)\, e^{-kt} \qquad (5.1)$$

While the cumulative infiltration capacity is expressed as:

$$f_p = f_b\, t + [\,(f_o - f_b)/K\,]\, e^{-kt} \qquad (5.2)$$

Where; f is the infiltration rate (mm/min), f_b is the final constant infiltration rate (Basic) at large times (mm/min), f_o is the initial infiltration rate (mm/min), f_p is the cumulative infiltration capacity (mm), and K is the soil parameter representing the rate of decrease of infiltration (min^{-1})

Horton's Equation can be used to describe the concepts of infiltration rate and basic infiltration, it requires evaluation of f_o , f_b and k (these parameters are derived based on infiltration tests (Linsley et al., 1988).

The infiltration parameters for the different soil type in Gaza Strip are evaluated from the experimental infiltration data done by Goris and Samain (2001) was shown in Table (5.3).

5.2.3.3 Computation of Recharge in Gaza Strip

Recharge from rainfall is perhaps the most difficult parameter to quantify in the Gaza Strip due to all of the potential factors that affect infiltration of rainwater. This include land use, soil type, as well as other influencing other factors (CAMP, 2000).

The groundwater is recharged from different sources, including rainwater, runoff and return flow which includes leakage from municipal water distribution system, sewage infiltration and irrigation return flow. Moreover, recharge comes from inflow from occupied areas and Egypt and from the Mediterranean Sea as a seawater intrusion.

As a result of absence of a specific study on the study area, the situation of the Gaza Strip as a whole has used. Rainfall is considered as the major recharge component that replenishes the aquifer. Only about 35% of the total rainfall can be infiltrated to replenish the groundwater in Gaza strip. Groundwater recharge from rainfall in Gaza strip is estimated as 40.46 Mm^3 for the season 2004/2005 (PWA, 2005). This value is almost equal to the average rainfall recharge (1974-2005 which is estimated as 40.8 Mm^3. The remaining amount of rainfall evaporates and /or disappears as runoff (PWA, 2005).

Rainfall is the main renewable resource that feeds the groundwater aquifer in the Gaza Strip. About 40% (46 Mm3/yr.) of the total rainfall is recharging the groundwater aquifer (Abu Mayla et al., 1998).

There is no simple method that can be applied to the Gaza strip. Empirical methods of estimating recharge tend to be applicable for smaller area only. therefore, in this research the recharge will be estimated using CAMP model which is a broader "regional" model. The model methodology considered the following procedures:

- Recharge from rainfall was applied in the model based on measured rainfall at stations and on soil distribution.
- Total rainfall reduced by factors to account for runoff (small, 5-10%) and (significant, 50-60%).
- The Model domain was subdivided into areas of different recharge coefficient based on soil distribution. These coefficient are primarily based on field data Israel estimates within Gaza Strip from the 1970s.

Applying these procedures, The recharge coefficients in Gaza Strip range from 70% of rainfall in dune sand to 15% of rainfall for silty clays.

The highest recharge coefficient of 70% is in dune sand areas parallel to coastlines. Overall, most recharge takes place in the north and northwest of Gaza strip, where total rainfall is highest and dune sand are present. Figure (5.7) shows the soil recharge coefficients for Gaza Strip (CAMP, 2000).

5.2.3.4 Procedures for Calculation of Recharge Rate of Study Wells

1. Determine the soil recharge coefficient of study wells:
    - Using Figure (5.7), the soil recharge coefficient of study wells was determined.
    - Table (5.4) shows the soil recharge coefficient of some study wells. The complete data of all study wells are represented in Annex 1.
2. Determine the rainfall depth fallen in the area of study wells:
    - The average rainfall depth fallen in Gaza strip catchments' area was calculated from daily rainfall records sourced from 12 manual stations using Thissen network method, in this method each station represents subarea of the catchments, and it involves in determining the area of influence for each station, as shown in Figure (5.8).
    - Using Figure (5.7), the influence station for each study wells was determined.
    - Table (5.4) shows the influence station for some study wells The complete data of all study wells are represented in Annex 1.
    - The rainfall data for Gaza Strip area are available, and so the rainfall depth was determined for each study well area.
3. The recharge rate was calculated directly by multiplying the soil recharge coefficient with rainfall depth. Complete data of recharge rate for study wells are found in Annex 3.

- **Example of calculation recharge rate for D/67 well at February, 1999 is presented as follows:**
    - Using Table (5.4), the soil recharge coefficient of D/67 well equals 0.70.
    - Using Table (5.4), the influence station of D/67 well is Bait lahia station.
    - The rainfall depth in February, 1999 is 19.5 mm and by multiplying the soil recharge coefficient with rainfall, the infiltration rate is 13.3 mm/m^2/month

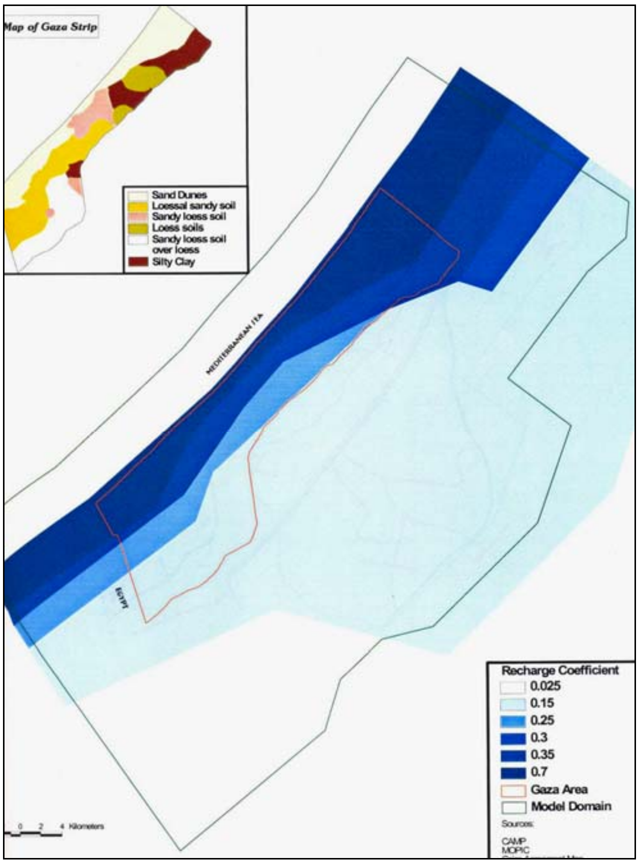

Figure (5.7): The soil recharge coefficients for Gaza Strip (CAMP, 2000)

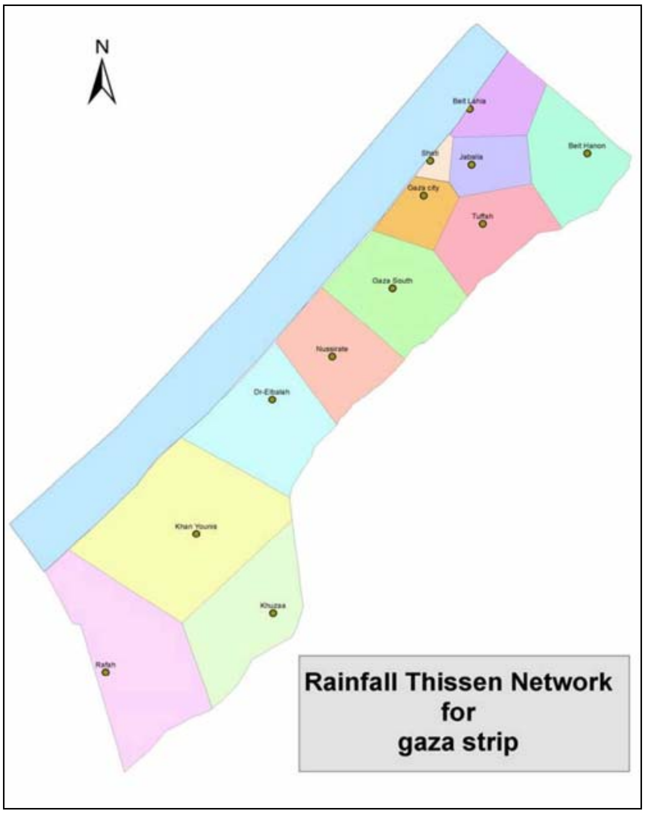

Figure (5.8): Rainfall thissen network for Gaza Strip catchment's area (PWA, 2007)

Table (5.4): Soil recharge coefficient, influence rainfall station, land use and soil type for each study wells

Ag No	Gov.	Rainfall Station	Land use	Soil type	Recharge coefficient
D/67	North	Bait lahia	open	Sandy regosol	0.70
A/180	North	Bait lahia	Built up	Sandy regosol	0.70
D/73	North	Bait lahia	open	Sandy regosol	0.70
D/72	North	Jabalia	open	Sandy regosol	0.70
E/61	North	Jabalia	open	Sandy regosol	0.70
A/185	North	Jabalia	Built up	Sandy regosol	0.70
D/71	North	Jabalia	open	Sandy regosol	0.70
C/127	North	Bait hanon	Built up	Sandy regosol	0.70
D/74	North	Jabalia	open	Sandy regosol	0.70
D/70	North	Jabalia	Built up	Sandy regosol	0.70

5.2.4 Abstraction

There is a significant uncertainty around historical pumping in Gaza; it is believed that large-scale abstraction started in the early 1960s, when agricultural development of the Gaza Strip began (PWA, 2002). Total groundwater abstraction in the Gaza Strip in 2000 is estimated at 140-145 MCM. Agricultural abstraction is estimated to account for about 85 MCM, while municipal 54 MCM. From the available data, the municipal wells abstraction in 2007 is about 83 MCM.

5.2.4.1 Agricultural Abstraction

It is estimated that more than 3800 agricultural wells are operational today. Agricultural wells have not been metered since 1994s, and hence current production totals are not exactly known. About 1500 wells were metered from about 1980-1993 during Israeli occupation. The Israeli Civil Administration reordered abstraction on a monthly, quarterly, and semi-annual basis. The metered data from the MOH indicated that the total average annual abstraction for the 1500 metered wells over the period of records (1988-1993) was approximately 43 MCM/y. prorating this average to the estimated 3800 wells in operation today, yields an estimated total agricultural abstraction of about 80-85 MCM/y.

Based on the above, it is reasonable to assume that agricultural abstraction has ranged between 80-100 MCM/y for the past 30 years. Independent of abstraction records, total agricultural demand has been estimated to be about 80-100 MCM/y based on cultivated areas and crop requirements, and is therefore consistent with abstraction data (PWA, 2002).

5.2.4.2 Municipal Wells Abstraction

Detailed abstraction records have not been obtained for years prior to 1996. Based on Israeli reports from 1970s, on pumping capacities, as well as information on typical pumping hours by season, it is estimated that municipal abstraction has increased from about 20 MCM in 1967 to 35 MCM in 1990, and 50 MCM in 1998.

The number of municipal supply wells has also increased from about 40 in 1973 to 56 in 1993 to 100 wells in 2000 In 2000, municipal abstraction totaled about 54 MCM/y. almost 50% of municipal abstraction take place in Gaza City and Jabalia (PWA,2002).

The production rate data of each municipal well in the Gaza strip were collected from the Coastal Municipal Water Utility (CMWU). From the available data the municipal wells abstraction in 2007 is about 83 MCM.

Table (5.5) presented the municipal abstraction in Gaza Strip for year 2007 and Figure (5.9) presents the monthly municipal abstraction in Gaza Strip for Year 2007.It is noted that the municipal abstraction are varies from month to other, In summer season there are huge abstraction specially in August and the abstraction decreases in winter specially in February.

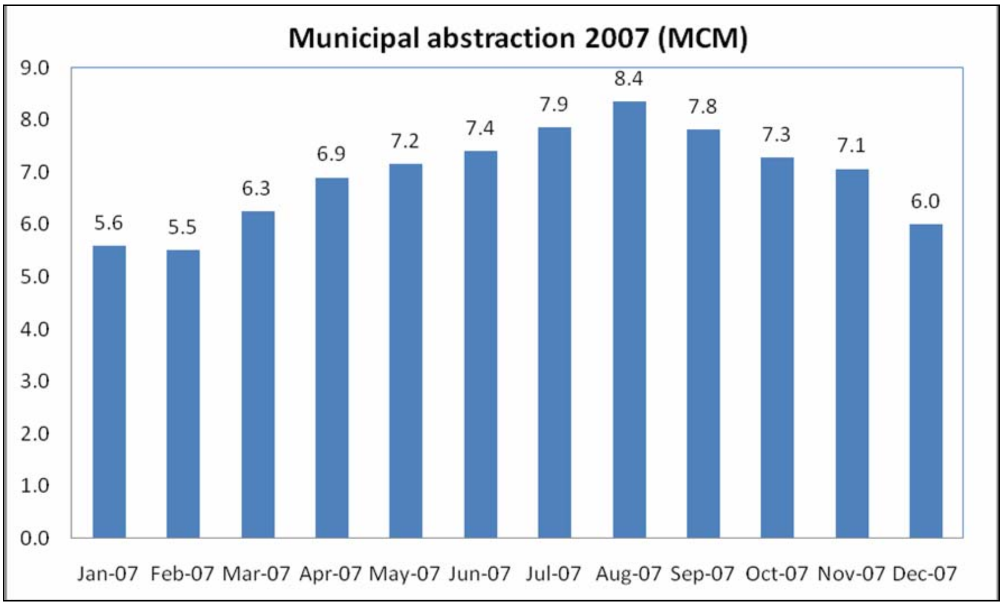

Figure (5.9): Monthly municipal abstraction in Gaza Strip for year 2007.

5.2.5 Distance From Sea Shore Line

Using ArcView program, the distance between the wells and sea shore line was measured and presented in Table (5.6). Complete data of distance between the wells and sea shore line for all study wells are found in Annex 1.

Table (5.6): The distance between the study wells and sea shore line

Ag No	Distance from sea shore line (Km)	Ag No	Distance from sea shore line (Km)
D/67	2.4	A/185	3.6
A/180	3.1	D/71	2.7
D/73	2.1	C/127	5.6
D/72	2.9	D/74	2
E/61	1.3		

Table (5.5) Monthly municipal abstraction in Gaza Strip for Year 2007

Municipality	Jan-07	Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07	**Total 2007**
Um AL Nasser	11,720	11,450	13,210	21,660	15,900	19,340	20,600	22,110	20,544	19,340	17,114	15,030	**208,018**
Beit Hanoon	208,400	203,940	238,880	369,400	300,520	379,010	419,540	424,020	383,802	379,010	288,620	257,320	**3,852,462**
Beit Lahia	348,671	378,285	440,106	523,413	354,356	425,284	599,812	543,927	449,673	425,284	459,496	360,380	**5,308,687**
Jabalia	755,247	831,589	994,228	996,847	1,224,341	1,096,069	1,171,282	1,311,935	1,280,050	1,096,069	1,078,140	857,221	**12,693,018**
Gaza	2,103,455	2,044,067	2,134,067	2,344,294	2,492,624	2,592,328	2,478,582	2,845,695	2,642,208	2,478,582	2,525,531	2,147,246	**28,828,679**
Wadi Gaza	5,080	4,980	6,350	8,760	10,610	6,940	7,090	5,600	6,170	6,940	3,470	3,580	**75,570**
Al Zahra	17,950	19,550	28,310	28,473	32,754	31,697	34,866	45,690	31,490	31,697	35,430	29,100	**367,007**
Al Moghrakah	15,793	16,720	19,117	32,740	46,762	46,273	56,591	42,774	50,793	46,273	31,200	27,203	**432,239**
Al Nussirate	183,630	199,110	175,130	225,393	225,830	311,430	316,020	347,859	278,061	311,430	213,980	207,780	**2,995,653**
Al Buriej	81,630	86,960	96,960	105,506	105,604	98,760	111,100	106,170	109,080	98,760	96,600	82,940	**1,180,070**
Al Maghazi	68,880	77,890	94,020	117,373	103,103	126,879	124,711	128,743	123,105	126,879	88,965	78,186	**1,258,734**
Deir Al Balah	288,227	297,965	308,773	353,521	360,966	329,965	421,742	394,883	424,238	329,965	351,421	322,181	**4,183,847**
Al Musader	8,430	6,770	7,270	10,000	8,310	10,430	10,810	11,830	5,750	13,250	7,480	5,890	**106,220**
Al Zawiada	60,440	62,060	70,025	83,403	90,943	64,600	113,049	102,824	81,877	64,600	77,940	79,870	**951,631**
Al Qarara	66,598	57,870	62,570	90,000	93,000	96,720	88,560	82,800	75,950	88,560	85,830	67,590	**956,048**
Bani Suhaila	73,270	79,560	91,670	111,960	111,810	98,040	137,720	139,430	132,430	98,040	111,560	90,510	**1,276,000**
Abassan Al Kabira	52,340	51,930	54,690	87,230	89,320	104,860	107,360	114,520	113,380	104,860	96,880	67,780	**1,045,150**
Abassan Al Jadidah	18,920	16,530	19,720	31,590	32,970	41,320	42,470	42,920	41,360	41,320	32,680	27,750	**389,550**
Khoza'a	29,080	28,900	32,490	44,660	45,770	54,250	65,460	65,020	65,460	54,250	48,560	35,570	**569,470**
KhanYounis	667,381	501,409	728,977	747,744	830,399	901,242	934,239	959,857	935,955	901,242	852,235	707,704	**9,668,384**
Al Fukhari	7,325	40,850	16,760	21,228	25,960	27,475	38,540	37,054	35,898	27,475	24,215	13,830	**316,610**
Al Nasser	9,230	6,280	7,030	7,430	7,340	9,090	8,660	12,780	13,000	9,090	13,100	12,690	**115,720**
Al Shokah	21,000	21,000	21,000	22,500	31,300	31,500	46,500	46,400	46,200	31,500	55,670	64,970	**439,540**
Rafah	498,843	467,335	607,293	523,483	524,578	510,155	510,155	523,799	487,067	510,155	477,080	442,955	**6,082,898**
Monthly Total	**5,601,540**	**5,513,000**	**6,268,646**	**6,908,608**	**7,165,070**	**7,413,657**	**7,865,459**	**8,358,640**	**7,833,541**	**7,294,571**	**7,073,197**	**6,005,276**	**83,301,205**

5.2.6 Water Level Data

Many estimation of the annual groundwater recharge in the Gaza Strip have been mentioned in different references. Although different values for this recharge are given, all of these references agree on one fact, that the annual recharge is less than the abstracted quantities for along time, resulting in a serious mining of the groundwater level and a net deficit of about 50-60 Million cubic meter (MCM)/year (CMWU, 2007).

Even though there is large database of water level information, few measurement are taken from dedicated monitoring wells. Water level reading are typically taken from active municipal and agriculture wells , in which the water level may be in a state of recovery after an unknown period of use. Often the well construction details are inaccurate or incomplete, Information about well screened is also unavailable, and measuring points of water level are often not truly fixed point, and some have changed over-time. In addition, access pipes in which water levels are measured are not always straight, which introducing more uncertainty into the accuracy of available data of groundwater level data on Gaza Strip. Groundwater heads in the aquifer fall from about 15 meters above mean sea level along the strip's eastern borders to mean sea level in the west along the shoreline. The depth of groundwater in the aquifer ranges between 60 meter along the eastern border drops to about 8 meter near the shore (Environmental Planning Directorate, 1996). Mortaja, (1998) reported that, the continuous over pumping from the aquifer has resulted in a drop of the water table at rate of (15 – 20) centimeter per year. Figure (5.10) presented the groundwater level contour map of Gaza Strip area for the year 2007.

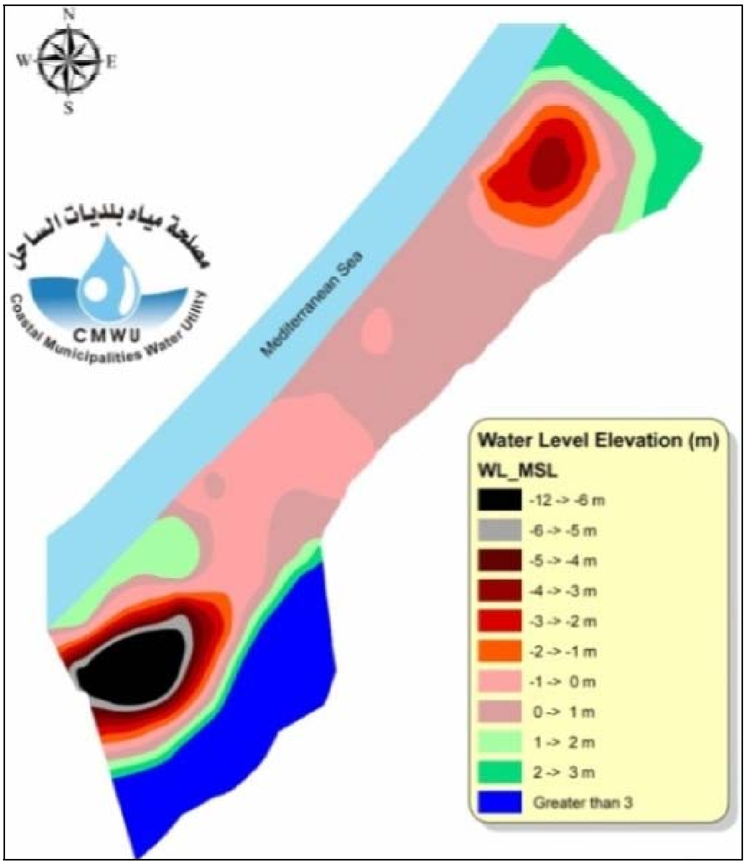

Figure (5.10): Groundwater level contour map of Gaza Strip area for the year 2007 (CMWU, 2007)

5.2.7 Depth From Ground Surface to Well Screen

The depth of groundwater in the aquifer ranges between 60 meter along the eastern border drops to about 8 meter near the shore (Environmental Planning Directorate, 1996). From the available data, we have the Z coordinate of study wells which is the level of ground surface and the level of well screen. So the depth from surface to well screen was calculated directly by subtract the level of well screen from the Z coordinate of study wells. Table (5.7) presented the depth from surface to well screen of some study wells. Complete data of depth from surface to well screen of all study wells the wells and sea shore line for all study wells are found in Annex 1.

Table (5.7): The depth from surface to well screen of some study wells

Ag No	Surface level	Top screen level	Depth from surface to screen (M)
D/67	22.9	-56.1	79
A/180	24.1	-57.9	82
D/73	37.2	-41.8	79
D/72	21.6	-24.4	46
E/61	44.8	1.8	43
A/185	40.6	-39.4	80
D/71	28	-22	50
C/127	57.2	-17.8	75
D/74	40	-41.4	81.4
D/70	24.9	-17.1	42

5.2.8 Saturated Aquifer Thickness

Within Gaza Strip, the coastal aquifer overlies the saqiye group, which is considered to be largely impermeable. The top of the saqiye group therefore marks the base the coastal aquifer. Approximately 10 to 15 km inland from the coast, the saqiye group pinches out, and the coastal aquifer rests directly on Eocene chalk and clastic sediments of Neogene age. The thickness of the entire coastal aquifer is on the average about 120 m. At the eastern Gaza border, the saturated thickness is about 60 m in the north, and only 5-10m in the south near Rafah. Localized perched condition may exist in the unsaturated zone throughout the Gaza Strip. Due to the presence of shallow fluvial and limnic clays (PWA, 2002).

5.2.8.1 Lithological Cross Sections

In literature 20 cross sections of the Gaza Strip were collected shown as Figures (5.11) and (5.12). These cross sections show the distribution of impervious to semi-impervious layers and lenses alternating with predominantly permeable sand and calcareous sandstones. These sections represent the upper part of Kurkar Group (costal aquifer) since the depths of the available wells are limited. Clay layers divide the aquifer vertically into four sub-aquifers as mentioned before A, B1, B2 and C .

The upper sub aquifer "A" is unconfined, whereas subaquifers "B1, B2, and C" become increasingly confined towards the sea .

5.2.8.2 Determination Aquifer Thickness of Each Study Wells

Lithological Cross Sections are prepared and drawn to scale and so it can be used to determine the depth of aquifer for each study wells as follows:.

- Select the lithological cross section number of each study wells.
- Select the distance between the well and sea shore line.
- Select the depth from surface to well screen and screen levels of wells
- After determining the previous variables, it easy to select the well subaquifer and determining aquifer thickness of each study wells.

Table (5.8) presented the Lithological cross section number, sub aquifer and saturated thickness of sub aquifer of some study wells. Complete data all study wells are found in Annex 1.

Table (5.8): The Lithological cross section number, sub aquifer and saturated thickness of sub aquifer of each study wells

Ag No	Section No.	Top. screen	Bot. screen	Sub aquifer	Sub aquifer thickness
D/67	99	-56.1	-66.1	C	80
A/180	99	-57.9	-67.9	C	90
D/73	99	-41.8	-51.8	A	53
D/72	99	-24.4	-48.4	A	41
E/61	99	1.8	-6.2	A	40
A/185	99	-39.4	-49.4	C	95
D/71	99	-22	-43	A	43
C/127	100	-17.8	-27.8	A	115
D/74	98	-41.4	-51.4	B2	50
D/70	99	-17.1	-65.1	A	40

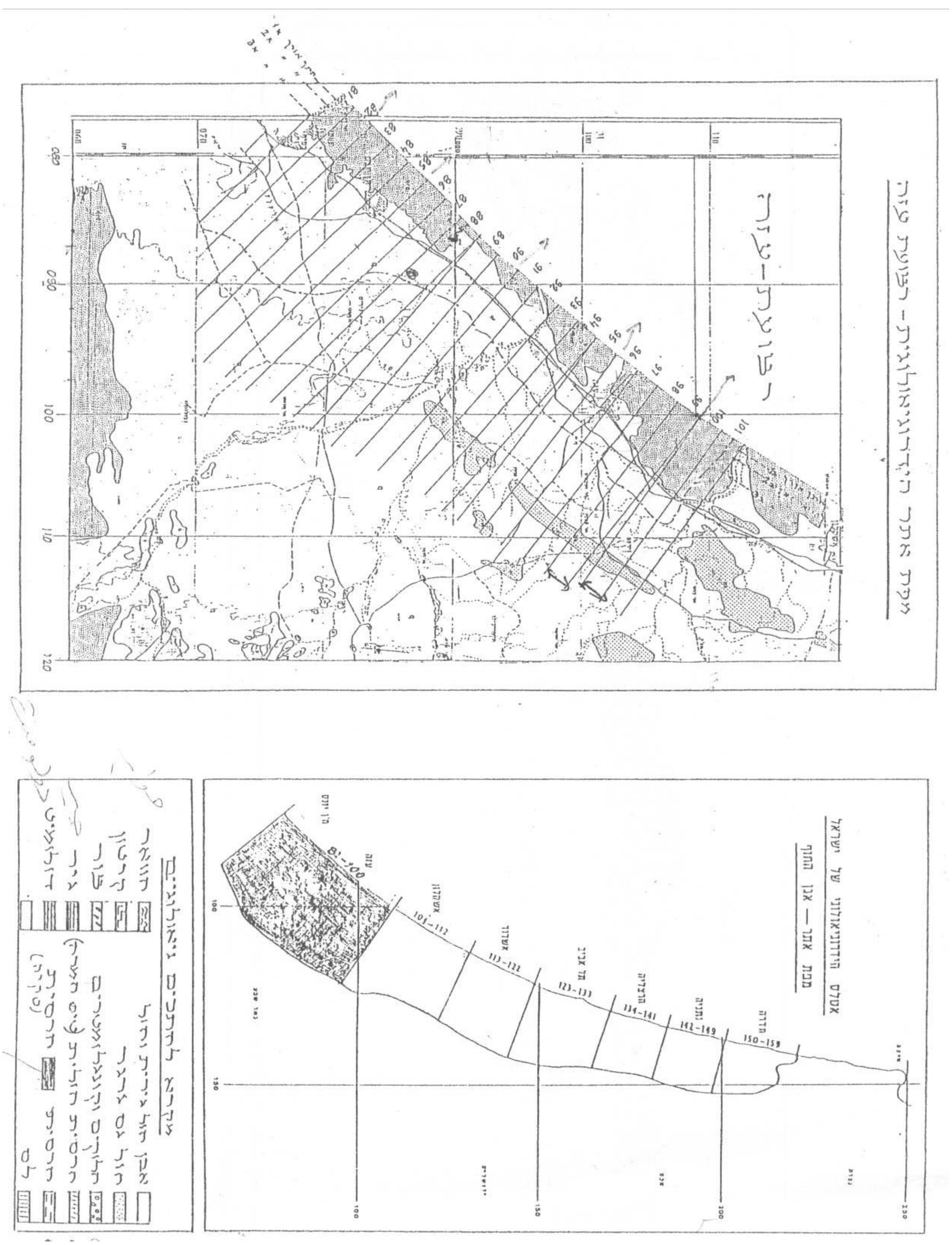

Figure (5.11): Lithological cross sections for Palestine and Gaza Strip (IWA , 1991)

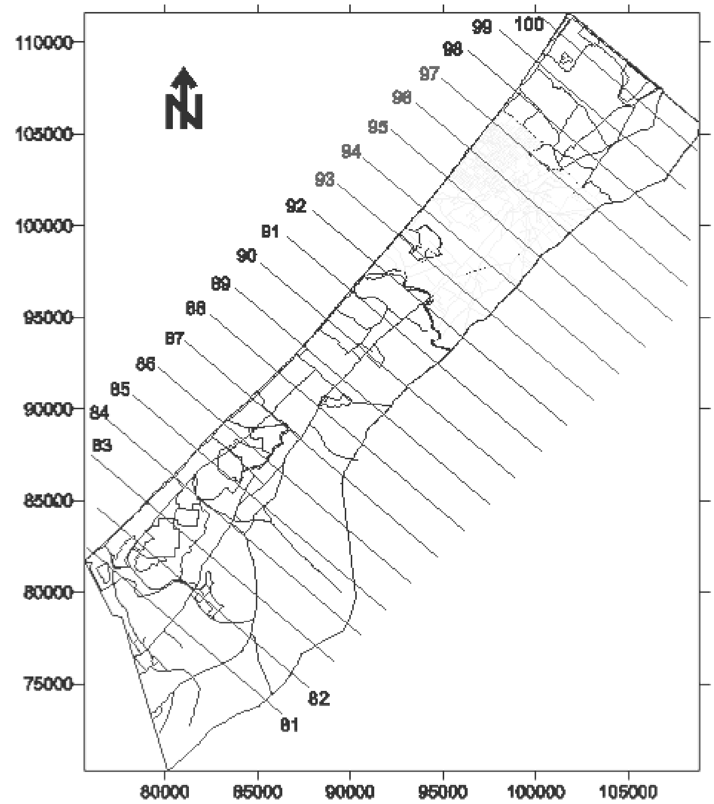

Figure (5.12.a): Lithological cross sections numbers for Gaza Strip Aquifer (IWA, 1991)

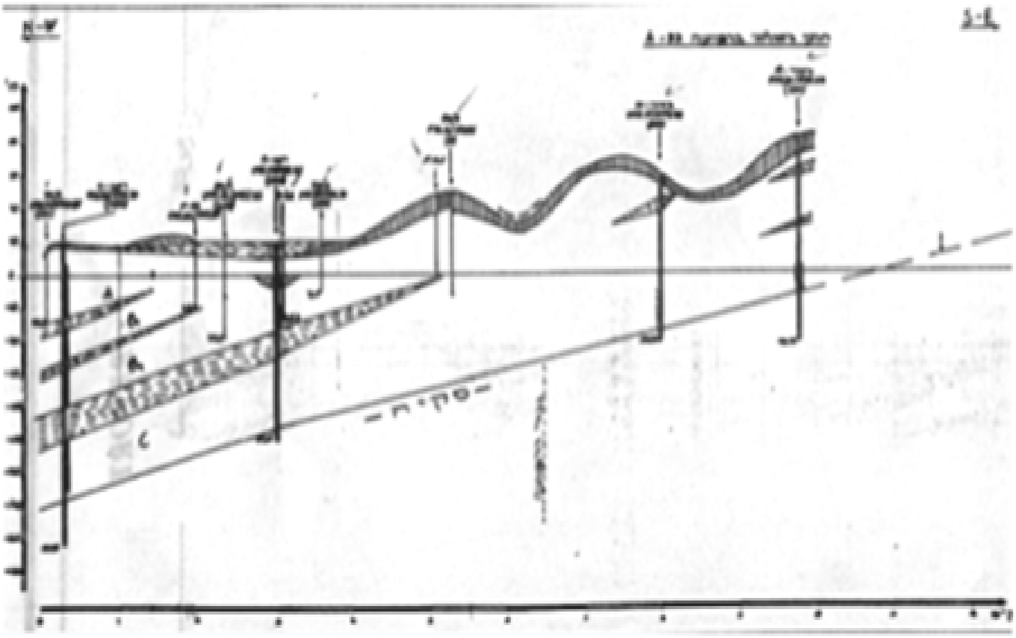

Figure (5.12.b): Geological cross section number 93 (IWA, 1991)

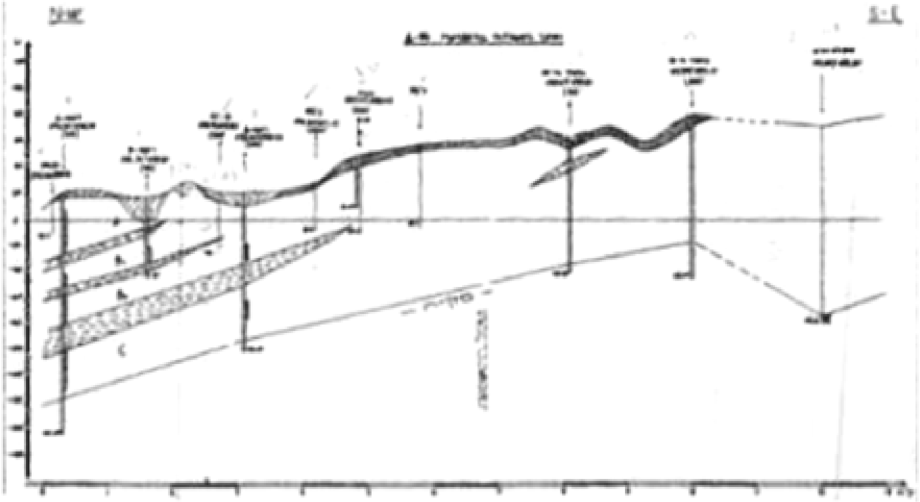

Figure (5.12.c): Geological cross section number 94 (IWA, 1991)

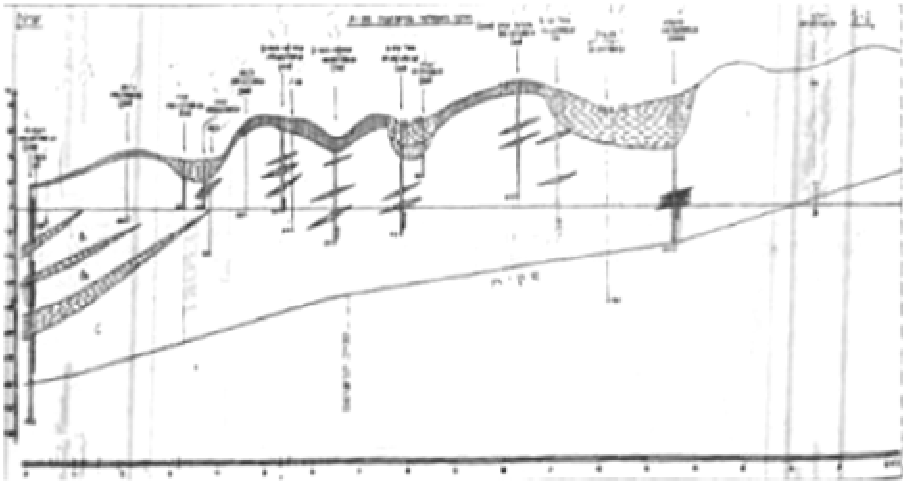

Figure (5.12.d): Geological cross section number 95 (IWA, 1991)

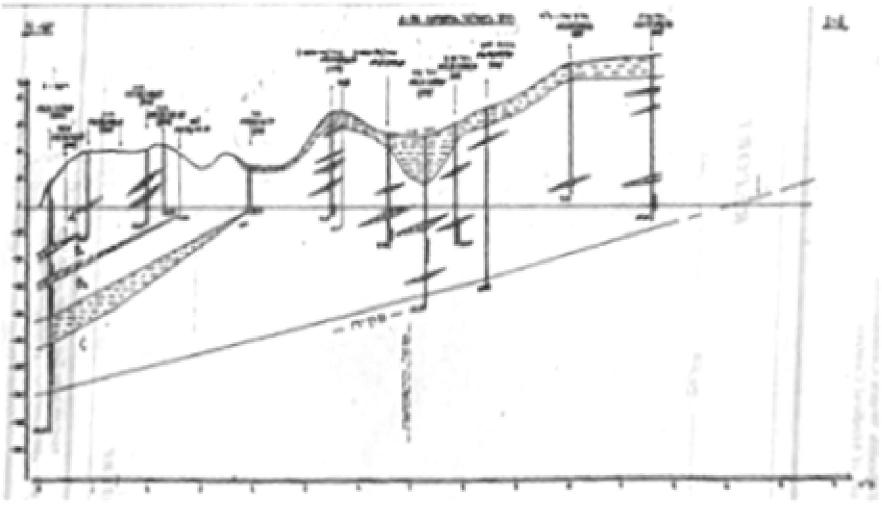

Figure (5.12.e): Geological cross section number 96 (IWA, 1991)

5.3 Construction Data Matrix for ANN Model

5.3.1 Selection the Variables of ANN Model

One of the critical issues in training the ANN model is to select input variables that are highly correlated with studied problem. The choice of variables (at least initially) is guided by intuition. Understanding and expertise in the problem domain and conditions gives initially idea of which input variables are likely to be influential. Once in ANN, variables can be selected and deselect, and ANN can also determine useful variables (Jiang and Cotton, 2004).

Hydrogeologically, the change of chloride concentration (salinity) depends on many variables such as infiltration, abstraction, life time of abstraction from aquifer, groundwater level, aquifer depth, aquifer thickness, and distance from sea shore line. These variables were discussed in previous sections. They were chosen to predict the chloride concentration which is a dependent of other variables. The chosen variables are described in Table (5.9).

Table (5.9): The variables of ANN model

	Variable	**Sym.**	**Unit**	**Type**
1	Final chloride concentration	Cl_f	mg/l	Dependent
2	Initial chloride concentration	Cl_o	mg/l	Independent
3	Recharge rate	R	$mm/m^2/month$	Independent
4	Abstraction	Q	$m^3/hour$	Independent
5	Abstraction average rate	Qr	$mm/m^2/month$	Independent
6	Life time	Lt	y	Independent
7	Groundwater level	Wl	m	Independent
8	Depth from surface to well	Dw	m	Independent
9	Aquifer thickness	Th	m	Independent
10	Distance from sea shore line	Ds	km	Independent

The ANN model operated under black box, that includes large number of complex mathematical functions as discussed in Chapter 3. Equation (5.3) represents - in simple way- the ANN model.

$$\mathbf{Cl_f = f\,(Cl_o, R, Q, Qr, Lt, Wl, Dw, Th, Ds)} \qquad (5.3)$$

5.3.2 Time Distribution Phases of ANN Model Data

The model data were extracted mainly from domestic wells in Gaza Strip because they usually have records of chloride concentration twice a year in February and October periodically. The time distribution divides the year in two phases A and B. The phase A starts from April to September and the phase B starts from October to March in next year. For example, time phase 1997-A extends from April 1997 to September 1997 , time phase 1997-B extends from October 1997 to March 1998 and time phase 1998-A extends from April 1998 to September 1998, etc. So all other factors were organized according to this time distribution. Table (5.10) presented the time distribution phase of the ANN model for the years 1997 and 1998

Table (5.10) The time distribution phase of the ANN model for the years 1997 and 1998

Year	Month	Time phase
1997	April	1997-A
1997	May	
1997	June	
1997	July	
1997	August	
1997	September	
1997	October	1997-B
1997	November	
1997	December	
1998	January	
1998	February	
1998	March	
1998	April	1998-A
1998	May	
1998	June	
1998	July	
1998	August	
1998	September	

5.3.3 Organizing of ANN Model Data

The organizing of ANN model data are required to construct some hundreds of data cases of input and output variables. These cases construct data matrix. Data organizing was carried out using software Ms. Excel and Access software. The data matrix is considered as row material to ANN model. Table (5.11) summarizes procedures of organizing ANN model variables.

Table (5.11): The procedures of organizing ANN model variables

	Variable	Sym.	Organizing procedures
1	Final chloride concentration	Cl_f	It is collected from PWA data bank. It is presented in Annex 2.
2	Initial chloride concentration	Cl_o	It is collected from PWA data bank. It is presented in Annex 2.

3	Recharge rate	R	It is calculated for each month as noticed in section 5.2.3.4 then it is summed to each time phase and the monthly rate was calculated. It is presented in Annex 3.
4	Abstraction	Q	Monthly abstraction quantities for study well is collected from PWA data bank. Then it is summed for each time phase and the hourly rate was calculated. It is presented in Annex 4.
5	Abstraction average rate	Qr	It was calculated for each governate in Gaza Strip by summation of all municipal abstraction quantities and divide it to the each governate area for each time phase. It is presented in Annex 5.
6	Life time	Lt	It is calculated directly by subtracting the year of operation from the time phase year. It is presented in Annex 1.
7	Groundwater level	Wl	It is collected from PWA data bank. It is presented in Annex 1.
8	Depth from surface to well screen	Dw	It is calculated directly by subtracting the level of well screen from the Z coordinate of study wells. It is presented in Annex 1.
9	Aquifer thickness	Th	It is calculated for each well as noticed in section 5.2.8.2. It is presented in Annex 1.
10	Distance from sea shore line	Ds	It is measured using Arc View program. It is presented in Annex 1.

By application the procedures in Table (5.11), the data matrix for ANN model were obtained. The entire data matrix are presented in Annex 6. Table (5.12) presented a side of ANN model matrix.

Table (5.12) Side of ANN model matrix.

Time phase	**Well**	**Cl_o**	**R**	**Q**	**Qr**	**Ot**	**Wl**	**Dw**	**Th**	**Ds**	**Cl_f**	**$Cl_{f\text{-}predicted}$**
1997-A	D/67	78.0	2.14	48.23	18.71	20	-2	79	80	2.4	55.0	95.7
1997-A	E/61	66.0	1.93	34.06	18.71	23	-1	43	40	1.3	145.0	120.1
1997-A	A/185	70.0	1.93	172.86	18.71	14	-2	80	95	3.6	100.0	61.2
1997-A	C/127	92.0	1.93	61.36	18.71	32	0	75	115	5.6	100.0	85.9
1997-A	D/74	56.0	1.93	139.37	18.71	0	-2	81	50	2.0	65.0	74.9
1997-A	D/68	92.0	1.93	177.38	18.71	9	-2	72	58	2.6	122.0	101.6
1997-A	D/60	142.0	1.93	56.81	18.71	38	-2	45	43	3.3	129.0	183.4
1997-A	C/79	427.0	0.96	0.00	18.71	27	0	64	90	6.4	384.0	438.6
1997-A	E/4	108.0	1.93	81.63	18.71	37	-1	34	124	4.7	100.0	94.4
1997-A	E/154	189.0	1.93	180.31	28.48	22	-2	92	50	1.7	180.0	222.3
1997-A	C/128	234.0	0.96	118.65	18.71	13	1	110	86	7.7	259.0	221.2
1997-A	E/157	142.0	1.93	198.43	18.71	11	-2	38	58	2.6	158.0	145.8
1997-A	E/156	135.0	1.93	151.75	18.71	17	-1	70	80	4.2	135.0	131.9
1997-A	E/90	142.0	1.93	74.01	18.71	27	-1	70	50	3.6	158.0	172.1
1997-A	R/162B	1295.0	1.42	188.15	28.48	31	-1	70	30	1.7	1505.0	1472.7
1997-A	R/162LA	262.0	1.35	126.23	28.48	11	-1	56	30	1.6	273.0	290.0
1997-A	R/162G	440.0	1.93	196.53	28.48	33	-1	90	70	2.3	489.0	476.4
1997-A	R/25A	397.0	1.35	116.88	28.48	17	-1	85	109	4.4	446.0	379.8
1997-A	R/25D	600.0	1.35	181.30	28.48	25	-1	50	109	4.5	619.0	627.0
1997-A	R/254	385.0	1.35	117.92	28.48	12	1	46	36	1.4	417.0	409.5
1997-A	S/69	365.0	0.29	96.78	16.36	15	-1	73	71	5.1	417.0	375.3
1997-A	J/146	517.0	0.29	95.09	16.36	13	-1	62	78	4.8	540.0	549.6

5.3.4 Analysis of ANN Model Data

Considering only those cases that have complete numeric values for all variables without any missing data, only 499 cases satisfy the above-mentioned criteria from 1997 to 2003. ANN model might perform well over an entire space only when the training data are evenly distributed in the space. As the current data are collected from limited sources (56 municipal wells), they may constitute clusters. Therefore, the distribution of each variables across its range in the database is examined.

The frequency distribution of different variables studied across the range of the 499 cases are represented graphically as histograms with normal distribution curve in Figure (5.13). The mean, standard deviation and ranges of different variables used to train the ANN is shown in Table (5.13). The entire data matrix are presented in Appendix 6.

Table (5.13): Mean , standard deviation and ranges of variables used to train the ANN model

Variable	Sym.	Unit	Mean	Std. Dev	Range	
					Min.	Max.
Initial chloride concentration	Cl_o	mg/l	333.07	253.94	28.00	1412.00
Recharge rate	R	mm/m^2/month	18.19	24.44	0.00	83.07
Abstraction	Q	m^3/hour	105.55	57.99	0.00	254.94
Abstraction average rate	Qr	mm/m^2/month	22.50	5.80	11.37	33.94
Life time	Lt	y	22.02	13.94	0.00	60.00
Groundwater level	Wl	m	-1.16	1.15	-4.00	1.00
Depth from surface to well screen	Dw	m	65.26	22.05	18.00	110.00
Aquifer thickness	Th	m	64.17	27.25	30.00	124.00
Distance from sea shore line	Ds	km	3.38	1.47	0.60	7.70
Final chloride concentration	Cl_f	mg/l	341.11	261.09	35.00	1744.10

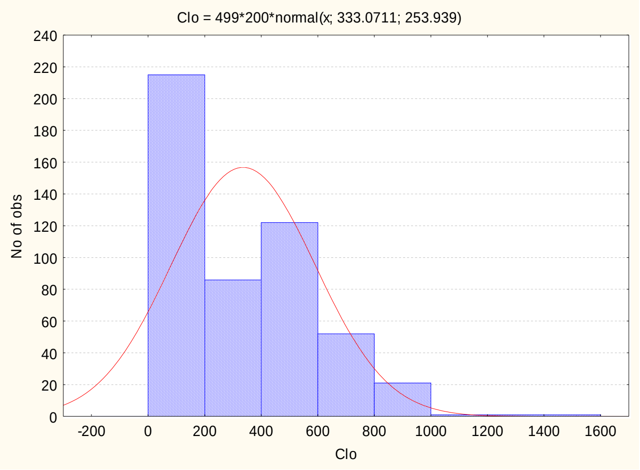

Figure (5.13.a): Frequency distribution of initial chloride concentration (Cl_o)

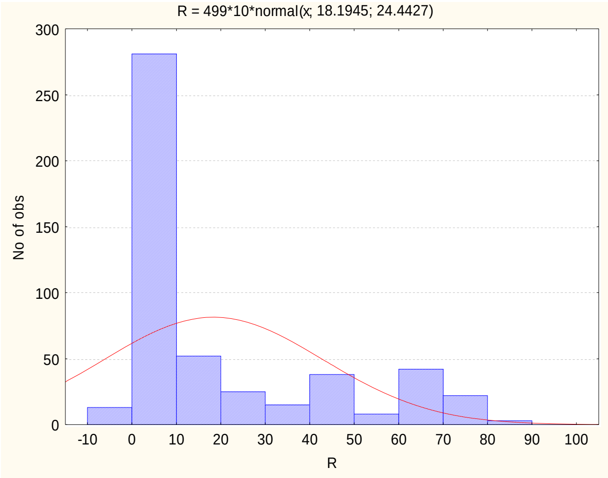

Figure (5.13.b): Frequency distribution of recharge rate (R)

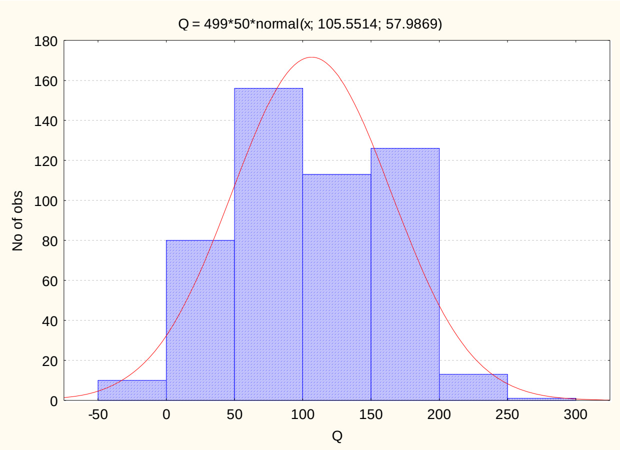

Figure (5.13.c): Frequency distribution of abstraction (Q)

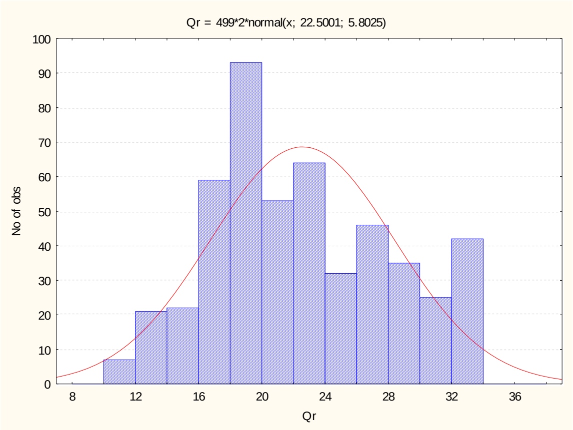

Figure (5.13.d): Frequency distribution of abstraction average rate (Qr)

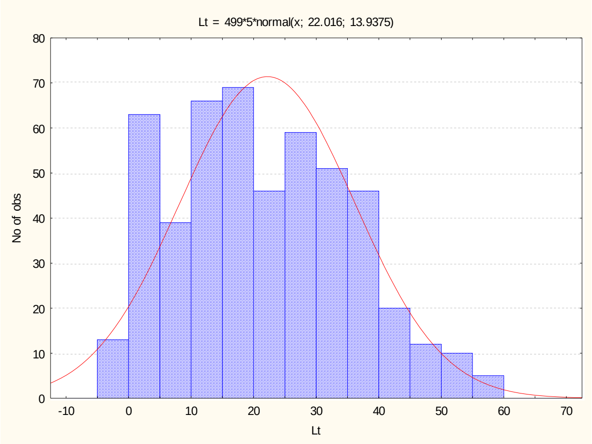

Figure (5.13.e): Frequency distribution of life time (Lt)

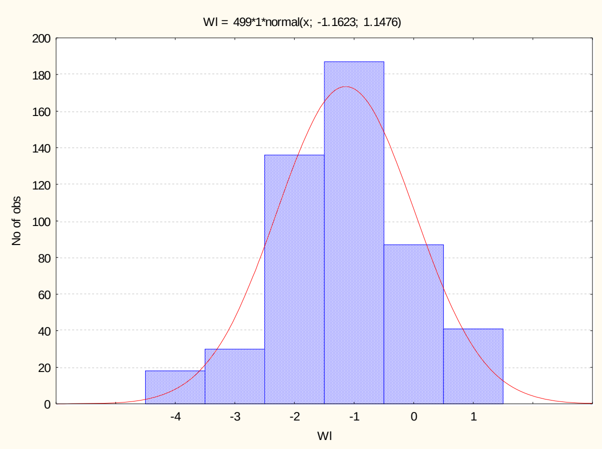

Figure (5.13.f): Frequency distribution of groundwater level (Wl)

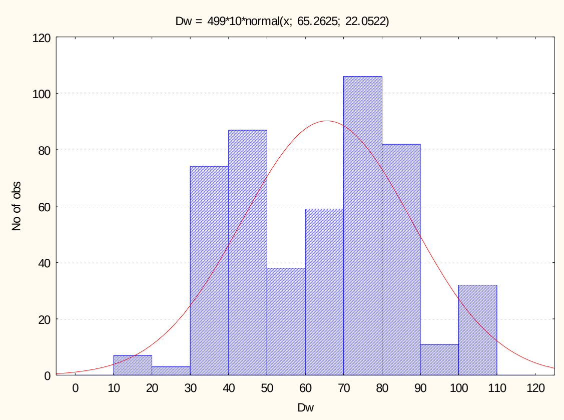

Figure (5.13.g): Frequency distribution of depth from surface to well screen (Dw)

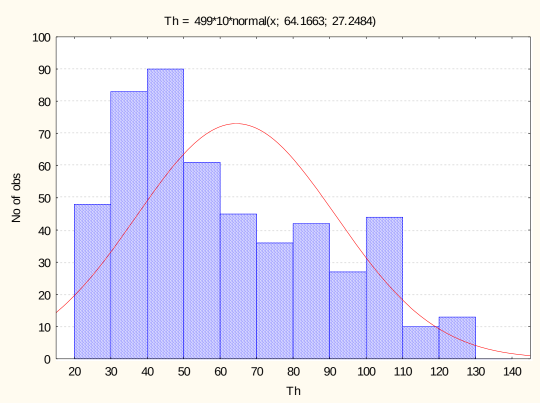

Figure (5.13.h): Frequency distribution of aquifer thickness (Th)

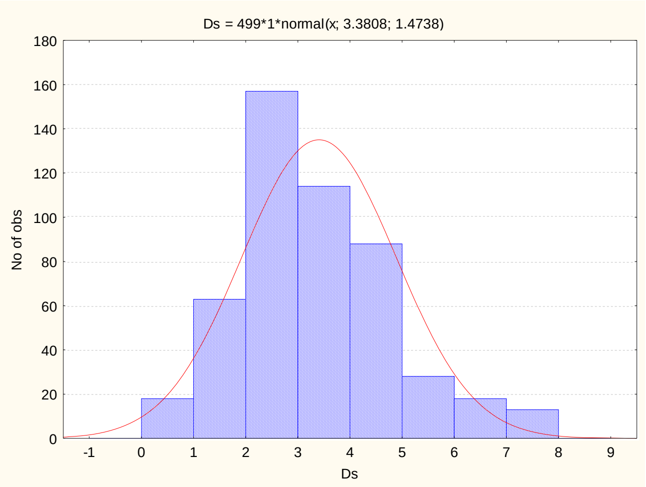

Figure (5.13.i): Frequency distribution of distance from sea shore line (Ds)

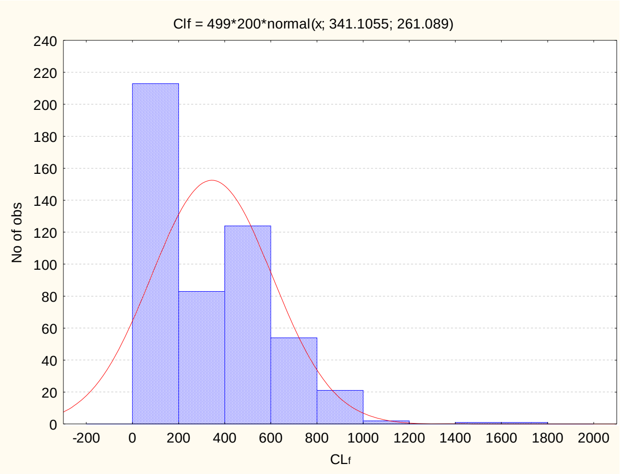

Figure (5.13.j): Frequency distribution of final chloride concentration (Cl_f)

Fig (5.13): Frequency distribution of the variables across the range of 499 cases

5.4 Procedural Steps in Building ANN Model

The ANN model was designed using the STATISTICA Neural Networks (SNN) which built in STATISTICA program version 7. STATISTICA, is a program where every analysis needed is at fingertips. Used around the world in more than 20 countries, StatSoft's STATISTICA line of software has gained unprecedented recognition by users and reviewers. In addition to both basic and advanced statistics, STATISTICA products offer specialized tools for analyzing neural networks, determining sample size, designing experiments, creating real-time quality control charts, reporting via the Web, and much more of the possibilities.

The procedural steps in building and applying for ANN model varies according to the tool used in building ANN models. Using SNN, the procedural steps involves the following procedures:

5.4.1 Data Importation

Feed the data matrix for SNN to train the Network by “importing” or through the data entry process. The data must be in acceptable format such as spreadsheet. The input data is the cases that the network use to train itself.

5.4.2 Problem Definition

Specify the inputs (Independent) and the output (Dependent) variable for the ANN model. Initially, there are nine inputs variables and one output variables as mentioned in Table (5.9).

5.4.3 Extraction of the Test Set

In SNN, The test set extraction is about 50% of cases for training. 25% for calibration and 25% for testing and it is randomly selected and the user can change these percentage. Test set provide a means by which the network knows when to stop training and used for calibration and Testing.

5.4.4 Network Design

Choose the appropriate architecture of network among the available networks based on the type of the data and the problem. This step was previously presented in section 3.6. After many trials, Multilayer Perceptron network (MLP) has been chosen because of its high capabilities to generalize well in problems plagued with significant heterogeneity and nonlinearity.

5.4.5 Network Training

Once the type of network has been chosen, the conditions to stop training processes was set before the network is trained. Training was controlled by some of conditions as: the maximum number of iterations, target performance which specifies the tolerance between the neural network prediction and actual output, the maximum run time and the minimum allowed gradient and .The overall training of the ANN will involve the following processes; the input values of the first layer are weighted and passed on to the hidden layer; the neurons in the hidden layer will produce outputs by applying an activation function to the sum of the weighted input values; the resulting outputs are then weighted by the connections between the hidden and output layer. The desired results are generated in the output layer.

The network achieves the desired learning by adjusting its interconnected weights continuously until there is a close match between the output from the neurons and the output from the training data. The difference between the predicted outputs and the original outputs is referred to as error.

5.4.6 Network Calibration

A trained network will continuously train in order to make a model perform best on the training set. However, after some time, it is very possible for the network to “memorize” the training set instead of learning it. In order to prevent the possibility of memorization to occur, calibration is utilized. Calibration is a parameter, which indicates that the network has trained enough thus stopping the iteration process. This can be achieved in two ways;

5.4.6.1 Calibration Based on Best Test Set

When training begins at the interval specified, the Network stops to read the test set and computes an average error for it. The error of the training set continues to decrease until it becomes flat whereas the test set error decreases to an optimal point after which it slowly increases. The Network could be saved at this optimal point based on the best test set.

5.4.6.2 Calibration Based on Minimum Error Events

Training was ordered to stop when the number of invents since minimum error for test set reaches a particular value. Calibration thus prevents over training of the network and thus reduces the training time.

5.4.7 Testing of Network

After the network has been successfully trained well, it is then tested against a set of cases withheld from it during its training session. The ANN is then ready to be applied to any other values of variables.

The results are then presented in statistical manner. Regression analysis is utilized to measure the degree of correlation between the actual output and the network output. Correlation factor (r) of 1 gives an indication of a perfect model while an (r) of 0 indicates a very bad model. Mathematically the values of (r) represented in equation (5.4). Detailed description for new built ANN model are presented in Chapter (6).

$$R^2 = 1 - \frac{\sum_{i=1}^{n}\left(actual_i - predicted_i\right)^2}{\sum_{i=1}^{n}\left(actual_i - mean\right)^2} \tag{5.4}$$

5.4.8 Application of the Network:

The built Network is then applied to any other values of input variables. The results can be displayed in statistical form to determine the correlation between the actual output and the predicted output. Detailed description about building and application ANN model are presented in Chapter (6).

Chapter (6)

Results and Discussion

6.1 Introduction

In this chapter, the procedural steps in building ANN model was applied in order to create new ANN model able to predict chloride concentration using the input variables which discussed in Chapter (5).

Many trials were applied to get best performance model. The initial modeling trials were made using all input variables. From created ANN models, the importance and effect of each variables was studied and represented, also the sensitivity analysis was applied. Depending on the results of ANN models some input variables were neglected and new modeling trials are made without using neglected input variables. The predicted values of chloride concentration were compared with the observed values of chloride concentration and the results presented in contour maps.

6.2 Characters of Initial ANN Model

6.2.1 Topology of ANN

Several ANN models were created and tested using SNN by varying the neural networks type, the number of hidden layers, number of neurons in hidden layers and stop training conditions parameters.

After a number of trials, the best neural network was determined to be **Radial Basis Function networks (RBF)** with three layers: an input layer of 9 neurons, one hidden layer with 44 neurons and the output layer with 1 neuron as shown in Figure (6.1). The nine input neurons are: initial chloride concentration (CL_o), recharge rate (R), abstraction (Q), abstraction average rate of area (Qr), life time (Lt), aquifer thickness (Th), groundwater level (Wl), depth from surface to well screen (Dw), and distance from sea shore line (Ds). The output neuron gives the final chloride concentration (CL_f). Figure (6.1)presented the topology of the ANN model.

6.2.2 Performance of ANN

The progress of the training was checked by plotting the training, and test mean square errors versus the performed number of iterations, Figure (6.2) presented the progress of the training proceses.

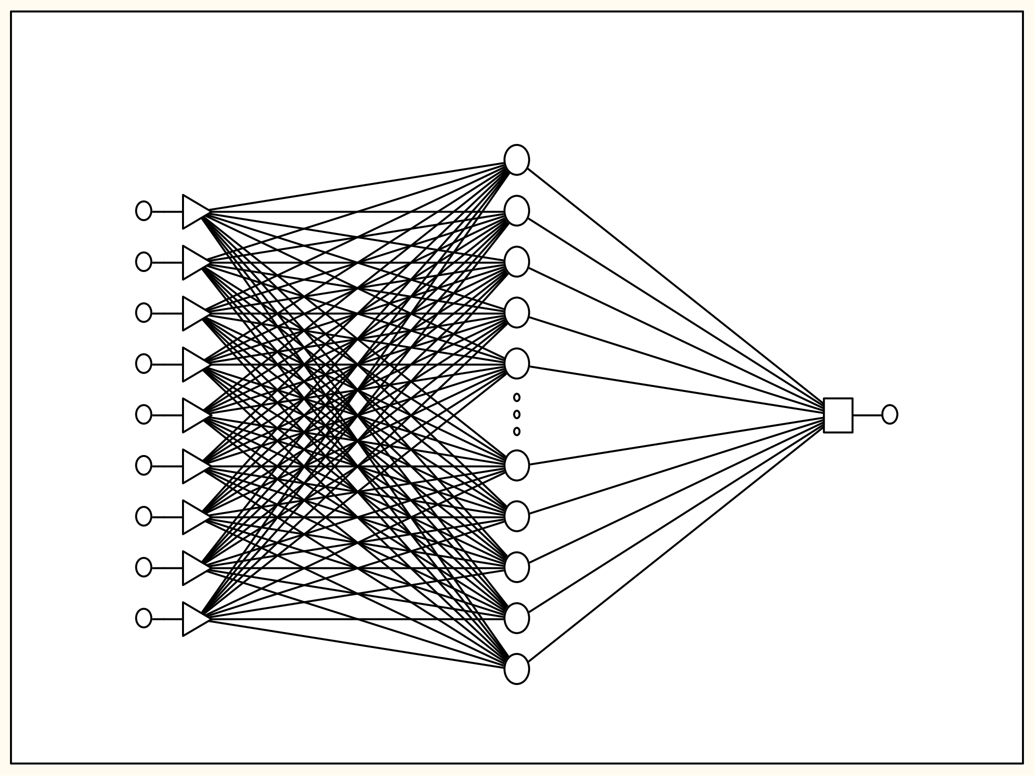

Figure (6.1): Topology of the ANN model

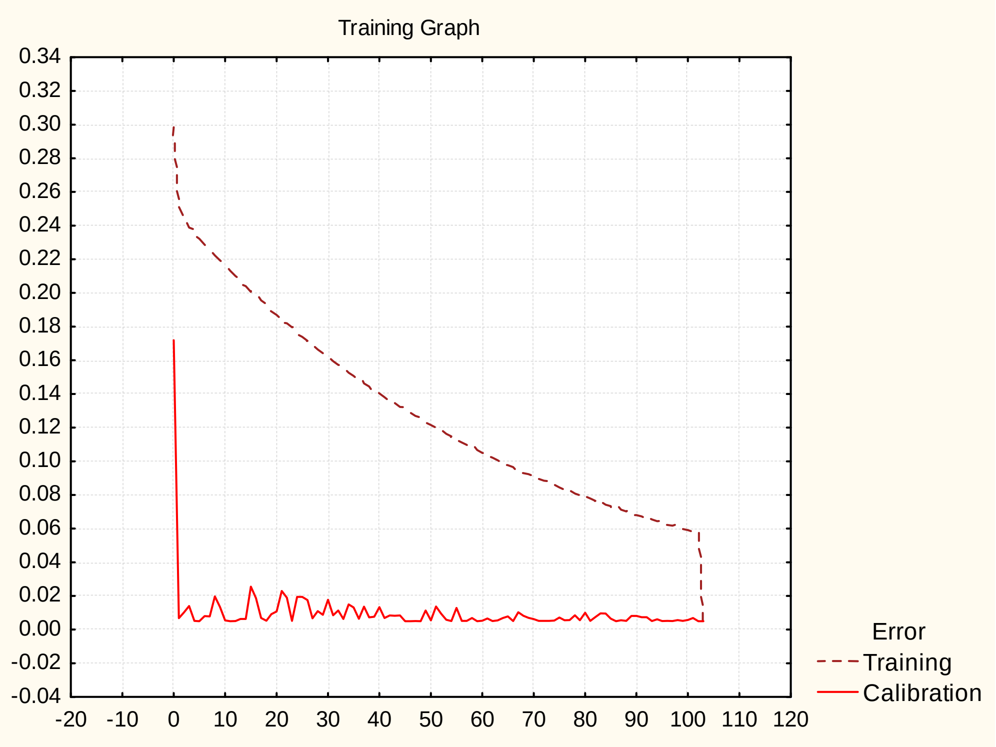

Figure (6.2): Training progress of ANN

Figure (6.3) presented a comparison of predicted chloride concentration using ANN and the observed chloride concentration. Figure (6.3) shows a high correlation between observed and predicted values of chloride concentration. The correlation coefficient (r) between the predicted and observed output values of the ANN model is 0.9635. Other Regression Statistics of ANN model were discussed and presented in section 6.2.3.

The high value of correlation coefficient (r) shows that the predicted chloride concentration values using the ANN model are in good agreement with the observed chloride concentration which give initial impression that ANN model are useful and applicable. Comparison between simulated chloride concentration using ANN and the observed chloride concentration on 1/10/2000 are presented in Figure (6.4).

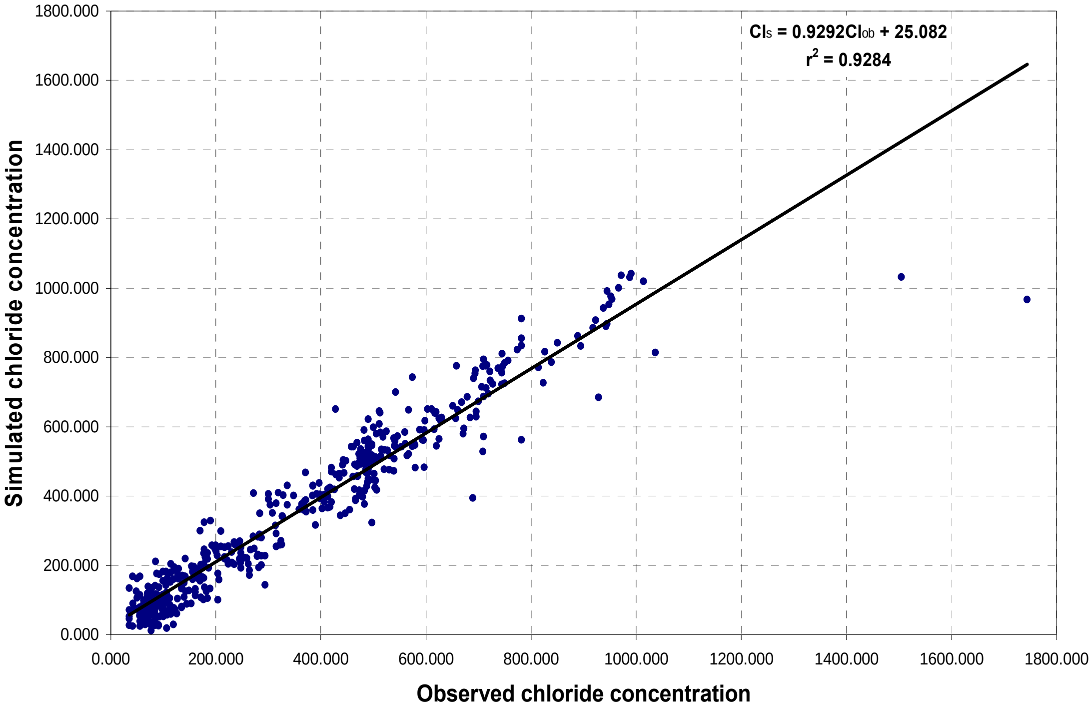

Figure (6.3): Comparison of simulated chloride concentration using ANN and the observed chloride concentration

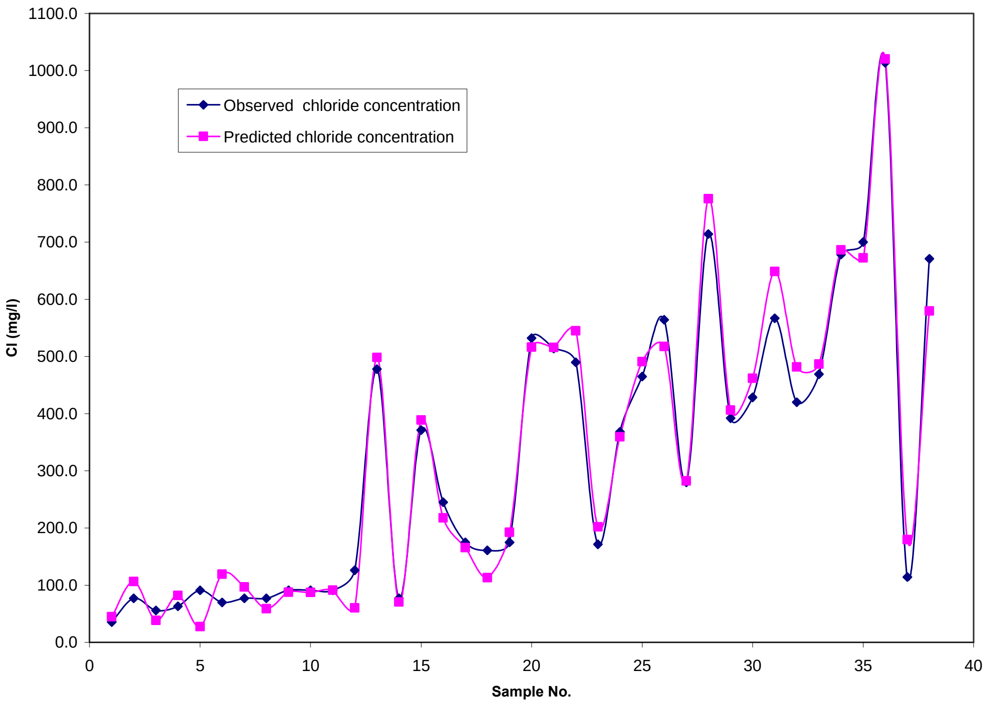

Figure (6.4): Comparison of simulated chloride concentration using ANN and the observed chloride concentration on 1/10/2000

6.2.3 Regression Statistics of ANN Model

In regression problems, the purpose of the neural network is to learn a mapping from the input variables to a continuous output variable. A network is successful at regression if it makes predictions with accepted accuracy.

SNN automatically calculates the mean and standard deviation of the training and other subsets, when the entire data set is run. It also calculates the mean and standard deviations of the prediction errors. The error ratio of the prediction to data standard deviations is displayed **(S.D. Ratio)** if it is 1.0, then the network is bad performance. A lower ratio indicates a better estimate.

In addition, SNN displays correlation coefficient (r) between the actual and predicted outputs. A perfect prediction will have a correlation coefficient of 1.0. A correlation of 1.0 does not necessarily indicate a perfect prediction (only a prediction which is perfectly linearly correlated with the actual outputs), although in practice the correlation coefficient is a good indicator of performance. It also provides a simple and familiar way to compare the performance of neural networks with standard least squares linear fitting procedures. The degree of predictive accuracy needed varies from application to application.

Regression statistics are listed as follows:

- **Data Mean**: Average value of the target output variable.
- **Data S.D.**: Standard deviation of the target output variable.
- **Error Mean**: Average error (residual between target and actual output values) of the output variable.
- **Abs. E. Mean**: Average absolute error (difference between target and actual output values) of the output variable.
- **Error S.D.**: Standard deviation of errors for the output variable.
- **S.D. Ratio**: The error/data standard deviation ratio.
- **Correlation**: The correlation coefficient (r) between the predicted and observed output values.

Table (6.1) present the values of regression statistics for the ANN model.

Table (6.1): The values of regression statistics for the ANN model

Regression statistics	**All model data**	**Training data set**	**Validation data set**	**Test data set**
Data Mean	341.1055	341.0527	361.3853	320.9324
Data S.D.	260.8273	259.5903	288.6549	230.7053
Error Mean	0.9367	0.0000	-3.4865	7.2561
Error S.D.	69.8102	57.5839	95.6191	60.7904
Abs E. Mean	44.3608	39.1642	54.0085	45.2320
S.D. Ratio	0.2676	0.2218	0.3313	0.2635
Correlation (r)	0.9635	0.9751	0.9439	0.9657

It was noted that the values of regression statistics for the ANN model refers that performance of ANN model is excellent as follows:

- Low value of **S.D. Ratio** shows that the error between observed and predicted chloride concentration values using the ANN model are small.
- High value of **correlation coefficient (r)** shows that the predicted chloride concentration values using the ANN model are in good agreement with the observed chloride concentration.

6.2.4 Response Presentations

Response presentations of initial ANN model are represented by response graph. which shows the effect on the output variable prediction of adjusting input (independent) variables. The ANN model was utilized to study the influence of the input variables on output variable which is chloride concentration.

Figure (6.5) presented response graphs of the input variables of ANN model. Figures (6.5.a,c,d,e,g,i) indicated that the chloride concentration increases nonlinearly as chloride concentration initial, abstraction, abstraction average rate, life time, groundwater level, and distance from sea shore line increase. Figures (6.5.b,f) indicated that the chloride concentration decreases nonlinearly as recharge rate and aquifer thickness increase. Figure (6.5.h) indicated that relations between chloride concentration and depth from surface to well screen is not stable.

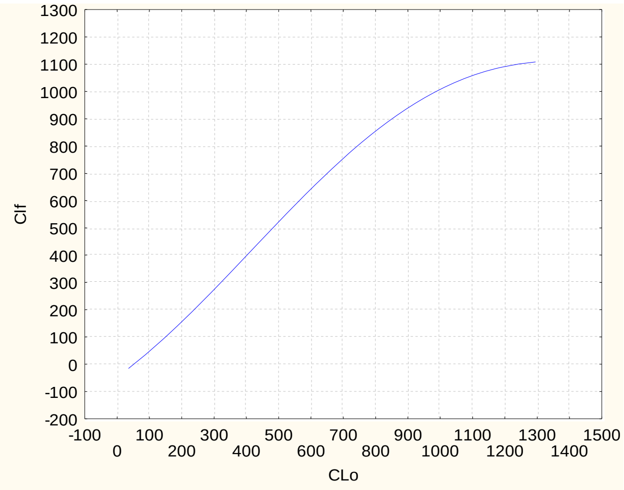

Figure (6.5.a) Response graph of Clo

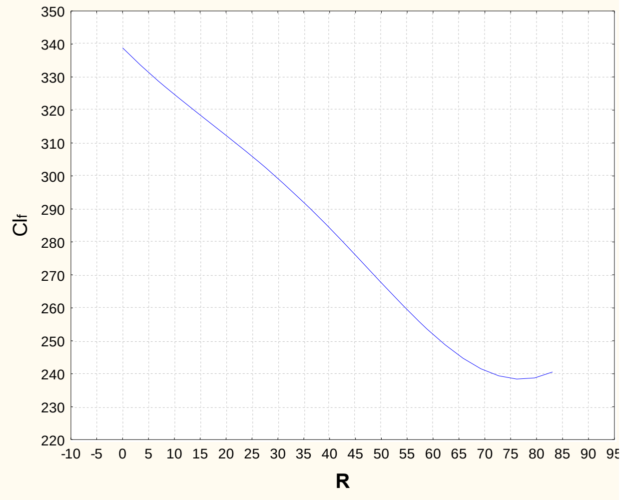

Figure (6.5.b) Response graph of R

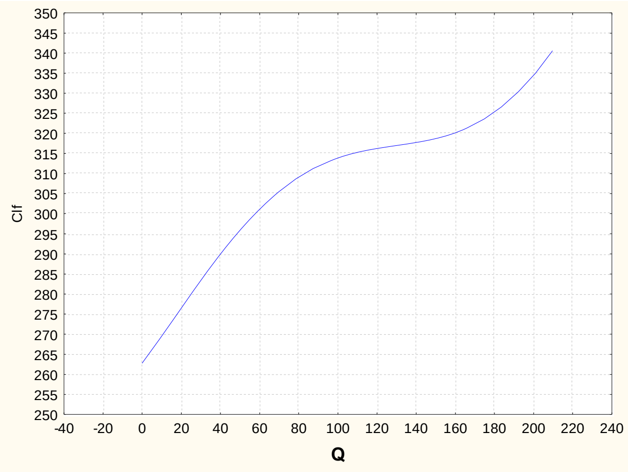

Figure (6.5.c) Response graph of Q

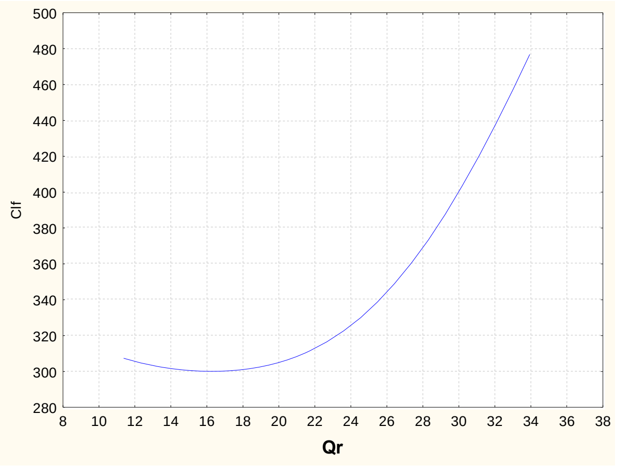

Figure (6.5.d) Response graph of Qr

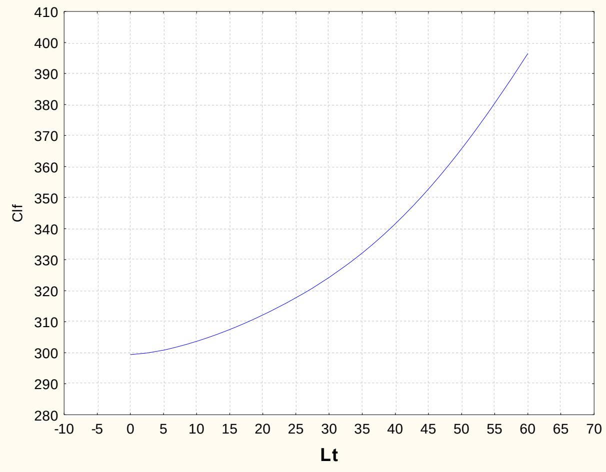

Figure (6.5.e) Response graph of Lt

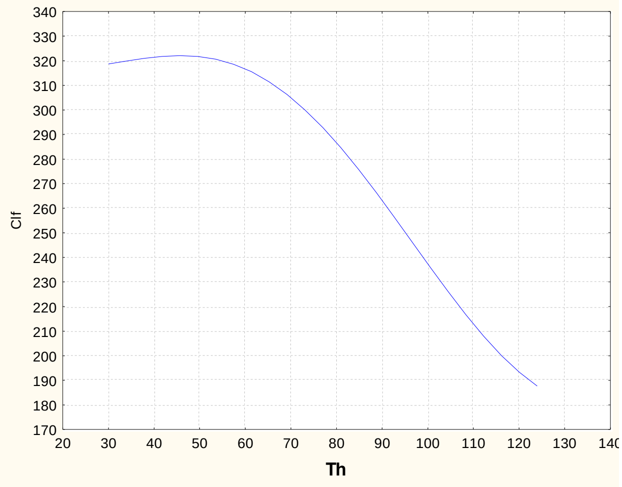

Figure (6.5.f) Response graph of Th

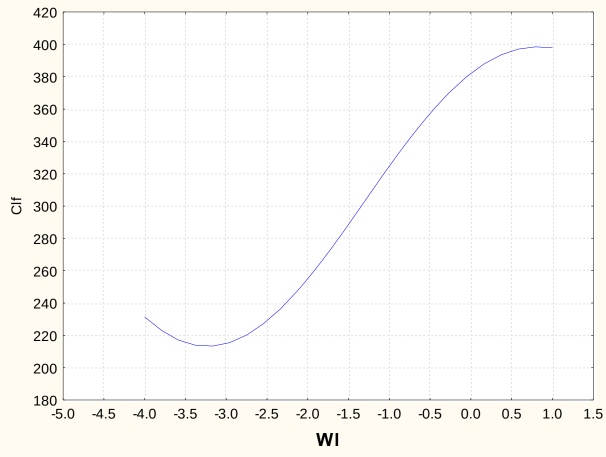

Figure (6.5.g) Response graph of Wl

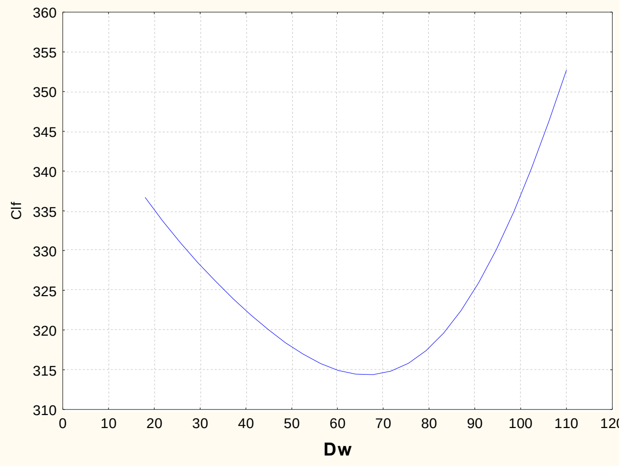

Figure (6.5.h) Response graph of Dw

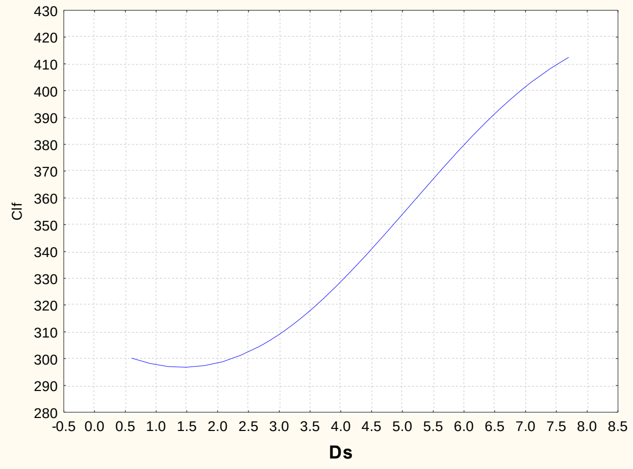

Figure (6.5.i) Response graph of Ds

Figure (6.5): Response graph of input variables for initial ANN

6.2.5 Sensitivity Analysis

SNN conducts a sensitivity analysis on the inputs to a neural network. This indicates which input variables are considered most important by that particular neural network. Sensitivity analysis can be used purely for informative purposes. Sensitivity analysis can give important insights into the usefulness of individual variables. It often identifies variables that can be safely ignored in subsequent analyses, and key variables that must always be retained. However, it must be deployed with some care, for reasons that are explained below.

Input variables are not, in general, independent - that is, there are interdependencies between variables. Sensitivity analysis rates variables according to the deterioration in modeling performance that occurs if that variable is no longer available to the model. In so doing, it assigns a single rating value to each variable. However, the interdependence between variables means that no scheme of single ratings per variable can ever reflect the subtlety of the true situation.

Consider, for example, the case where two input variables encode the same information (they might even be copies of the same variable). A particular model might depend wholly on one, wholly on the other, or on some arbitrary combination of them. Then sensitivity analysis produces an arbitrary relative sensitivity to them. Moreover, if either is eliminated the model may compensate adequately because the other still provides the key information. It may therefore rate the variables as of low sensitivity, even though they might encode key information. Similarly, a variable that encodes relatively unimportant information, but is the only variable to do so, may have higher sensitivity than any number of variables that mutually encode more important information.

SNN conducts sensitivity analysis by treating each input variable in turn as if it were "unavailable". SNN has defined a missing value substitution procedure, which is used to allow predictions to be made in the absence of values for one or more inputs. To define the sensitivity of a particular variable, v, the network first was run on a set of test cases, and the network error was accumulated. Then the network was run again using the same cases, but this time replacing the observed values of v with the value estimated by the missing value procedure, and again the network error was accumulated. (STATISTICA, 2004).

After that, It is expected some deterioration in error to occur. The basic measure of sensitivity is the ratio of the error with missing value substitution to the original error. The more sensitive the network is to a particular input, the greater the deterioration we can expect, and therefore the greater the ratio. Once sensitivities have been calculated for all variables, they may be ranked in order. SNN provides these rankings, for convenience in interpreting the sensitivities. Table (6.2) presented the value of error Ratio Rank of input variables.

Table (6.2): The value of error ratio and rank of input variables

Variables	Cl_o	R	Q	Qr	Lt	Th	Wl	Dw	Ds
Error Ratio	**3.08**	**1.04**	**1.05**	**1.09**	**1.10**	**1.08**	**1.02**	**1.07**	**0.99**
Variables Rank	**1**	**7**	**6**	**3**	**2**	**4**	**8**	**5**	**9**
Training error ratio	3.62	1.05	1.18	1.17	1.22	1.12	1.04	1.11	1.01
Training variables Rank	1	7	3	4	2	5	8	6	9
Validation error ratio	2.64	1.02	0.95	1.02	1.06	1.03	1.01	1.05	0.96
Validation variables Rank	1	6	9	5	2	4	7	3	8
Test error ratio	3.06	1.06	1.03	1.11	1.00	1.15	1.02	1.06	1.02
Test variables Rank	1	4	6	3	9	2	8	5	7

It was noted that value of Error Ratio of the initial chloride concentration (Cl_o) is the highest value of Error Ratio which mean that the final Chloride concentration (Cl_f) is high correlated to initial chloride concentration (Cl_o). The most other important variables for this model is life time (Lt), abstraction average rate of area (Qr) and aquifer thickness (Th). Other variables rank are presented in Table (6.2).

6.2.6 Determination the Real Importance of Input Variables

Sensitivity analysis does not rate the "usefulness" of variables in modeling in a reliable or absolute manner. The cautious is needed during drawing the conclusions about the importance of variables. Nonetheless, in practice it is extremely useful. If a number of models are studied, it is often possible to identify key variables that are always of high sensitivity, others that are always of low sensitivity and "ambiguous" variables that change ratings and probably carry mutually redundant information (SNN, 2004).

To determine the real importance and ranking of variables, twenty ANN models were created and sensitivity analysis was applied and results of sensitivity analysis were presented in Table (6.3).

Table (6.3): Sensitivity analysis of twenty ANN models

Model No.	Cl_o	R	Q	Qr	Lt	Th	Wl	Dw	Ds
1	2.95	1.02	1.00	0.98	0.98	0.98	0.98	1.02	1.01
2	3.22	1.02	0.98	1.06	1.01	1.00	0.99	1.02	1.04
3	3.52	1.00	1.04	1.01	1.02	1.04	1.03	0.98	1.04
4	3.00	0.99	1.00	0.99	1.01	1.02	1.01	0.98	0.99
5	3.14	0.99	1.00	0.98	0.99	0.99	1.00	0.98	0.96

6	3.06	1.00	1.00	1.01	1.01	1.00	1.00	0.98	0.95
7	3.51	0.99	1.00	1.02	1.03	1.02	1.00	1.00	0.96
8	3.27	1.00	1.00	1.00	1.01	0.98	1.00	0.99	0.97
9	3.54	0.99	1.01	0.99	1.02	1.01	1.01	1.00	0.97
10	3.51	1.01	1.01	1.02	1.04	0.99	1.00	0.99	0.99
11	2.72	1.01	1.00	1.04	0.98	1.04	1.02	0.97	0.98
12	2.96	0.99	1.05	1.08	0.98	1.02	1.04	0.99	0.98
13	3.09	1.00	1.01	1.12	1.03	1.15	1.03	0.97	1.03
14	3.08	1.04	1.05	1.09	1.10	1.08	1.02	1.07	0.99
15	3.23	1.02	1.01	1.02	0.98	0.98	1.01	1.00	0.97
16	3.57	1.01	1.01	1.09	1.00	1.06	1.01	1.04	1.01
17	3.65	1.04	1.00	1.04	1.01	1.04	1.01	1.03	0.98
18	3.74	1.02	1.01	1.08	1.01	1.06	1.02	1.02	1.00
19	4.10	1.05	1.01	1.05	1.05	1.03	1.04	1.01	1.00
20	4.24	1.05	1.04	1.08	1.05	1.01	1.01	1.02	1.02
Total	**67.10**	**20.26**	**20.23**	**20.73**	**20.32**	**20.49**	**20.23**	**20.07**	**19.85**
Average	**3.355**	**1.013**	**1.012**	**1.037**	**1.016**	**1.024**	**1.011**	**1.004**	**0.992**
Rank	**1**	**6**	**5**	**2**	**4**	**3**	**7**	**8**	**9**

From the results in Table (6.3), the variables can be ranked as described in Table (6.4). This rank is needed to identify variables that can be safely ignored in subsequent modeling, and key variables that must always be retained. From the result three variables with lowest sensitivity which is groundwater level (Wl), depth from surface to well screen (Dw), and distance from sea shore line (Ds) can be ignored in subsequent modeling.

Table (6.4) Rank of ANN model variables extracted from twenty ANN models

Rank	Variable	Action
1	Initial chloride concentration	Retained
2	Abstraction average rate	Retained
3	Live time	Retained
4	Aquifer thickness	Retained
5	Abstraction	Retained
6	Recharge rate	Retained
7	Ground water level	Ignored
8	Depth from surface to well	Ignored
9	Distance from sea shore line	Ignored

6.3 Characters of the Final ANN Model

6.3.1 Topology of ANN

Depending on the results of ANN models in Table (6.3), three input variables were neglected and new training trials are made without using neglected input variables. The neglected input variables is groundwater level, depth from surface to well screen, and distance from sea shore line.

Several ANN models were created and tested using SNN by varying the neural networks type, the number of hidden layers, number of neurons in hidden layers and stop training conditions parameters.

After a number of trials, the best neural network was determined to be **Multilayer Perceptron network (MLP)** with four layers: an input layer of 6 neurons, first hidden layer with 10 neurons, second hidden layer with 7 neurons and the output layer with 1 neuron as shown in Figure (6.6). The six input neurons are: initial chloride concentration (Cl_o), recharge rate (R), abstraction (Q), abstraction average rate of area (Qr), life time (Lt), aquifer thickness (Th). The output neuron gives the final chloride concentration (Cl_f).

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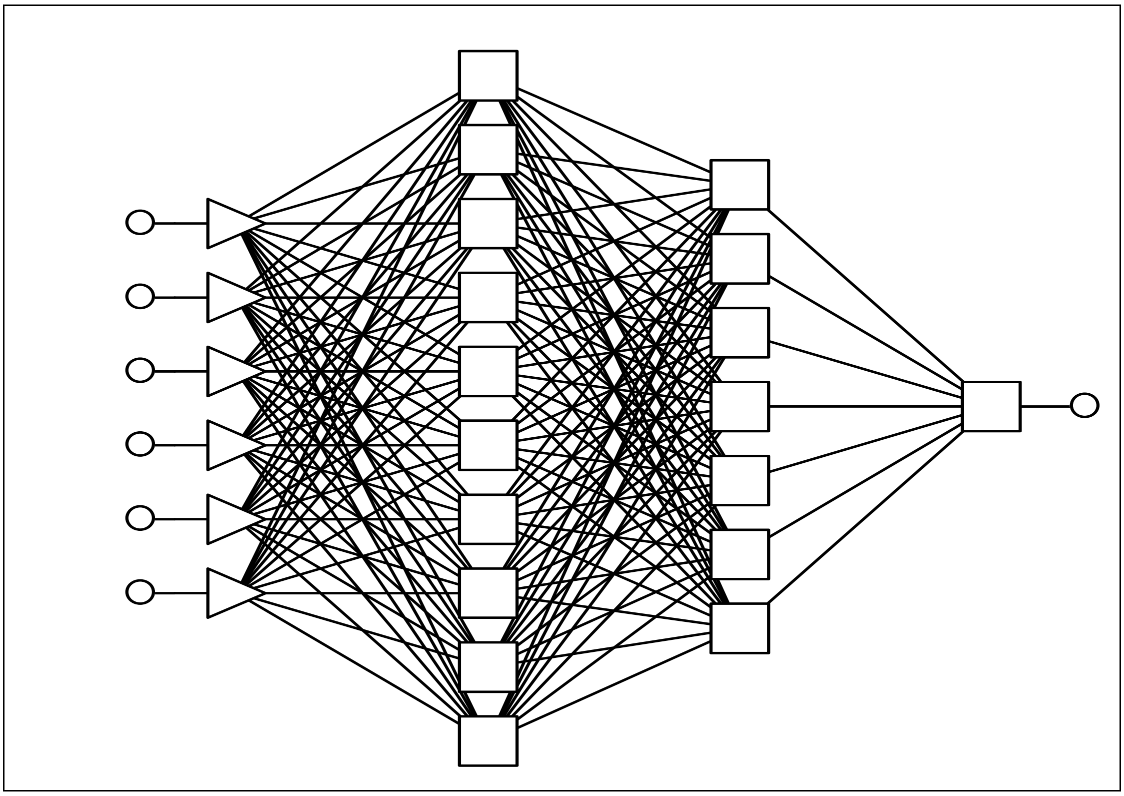


Figure (6.6): Topology of final ANN model

6.3.2 Performance of ANN

The progress of the training was checked by plotting the training, and test mean square errors versus the performed number of iterations, as presented in Figure (6.7).

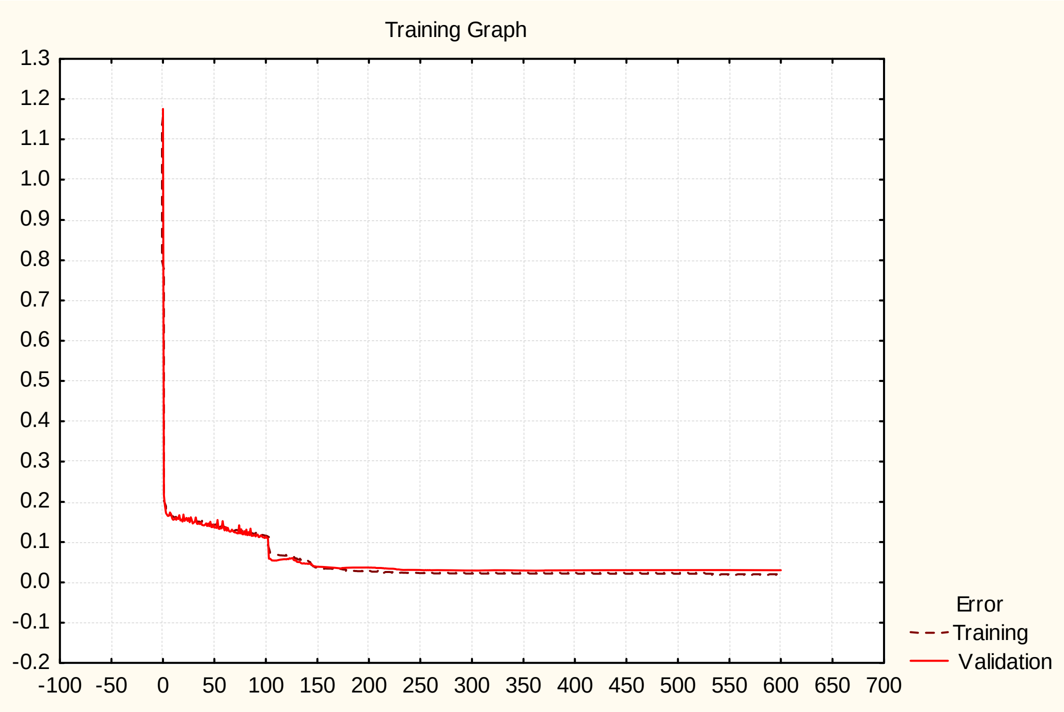


Figure (6.7): Training progress of ANN

Figure (6.8) presented a comparison of simulated chloride concentration using ANN and the observed chloride concentration. The Figure (6.8) showed a very high correlation between the observed and predicted values of chloride concentration. The correlation coefficient (r) between the predicted and observed output values of the ANN model is 0.9848. Other Regression Statistics of ANN model were discussed and presented in section 6.3.3. The high value of correlation coefficient (r) showed that the simulated chloride concentration values using the ANN model were in very good agreement with the observed chloride concentration which gave initial impression that ANN model are useful and applicable. Simulated chloride concentration using ANN model and observed chloride concentration on 1/10/2000 are presented in Figure (6.9).

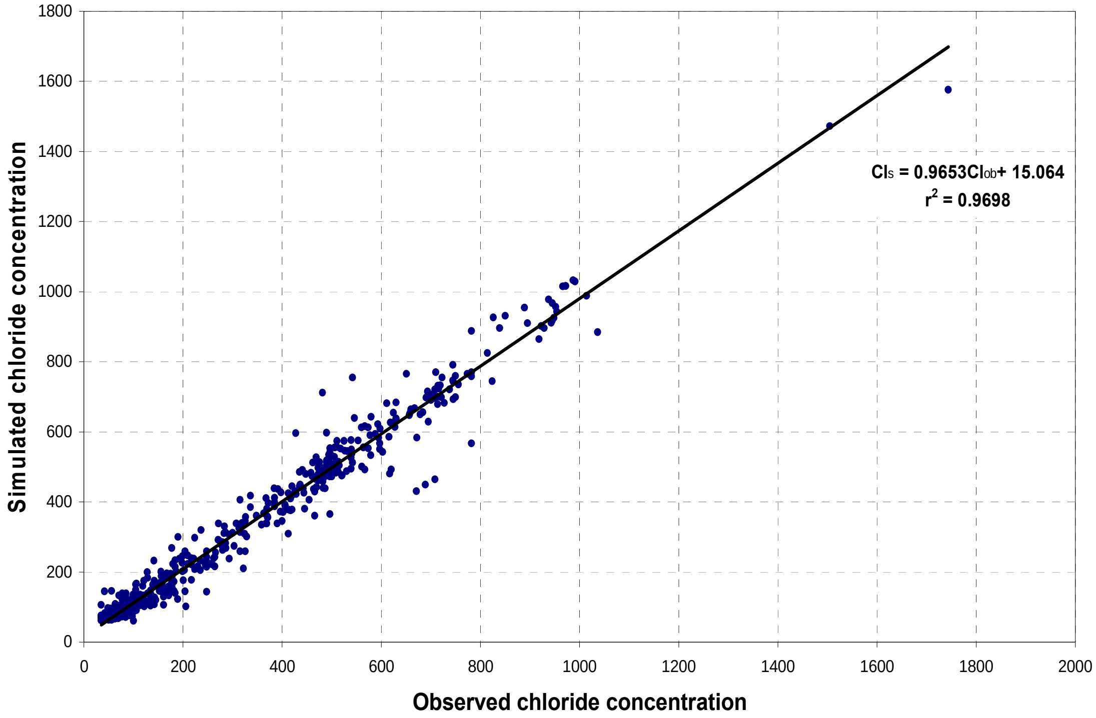


Figure (6.8): Comparison of simulated chloride concentration using ANN model and the observed chloride concentration

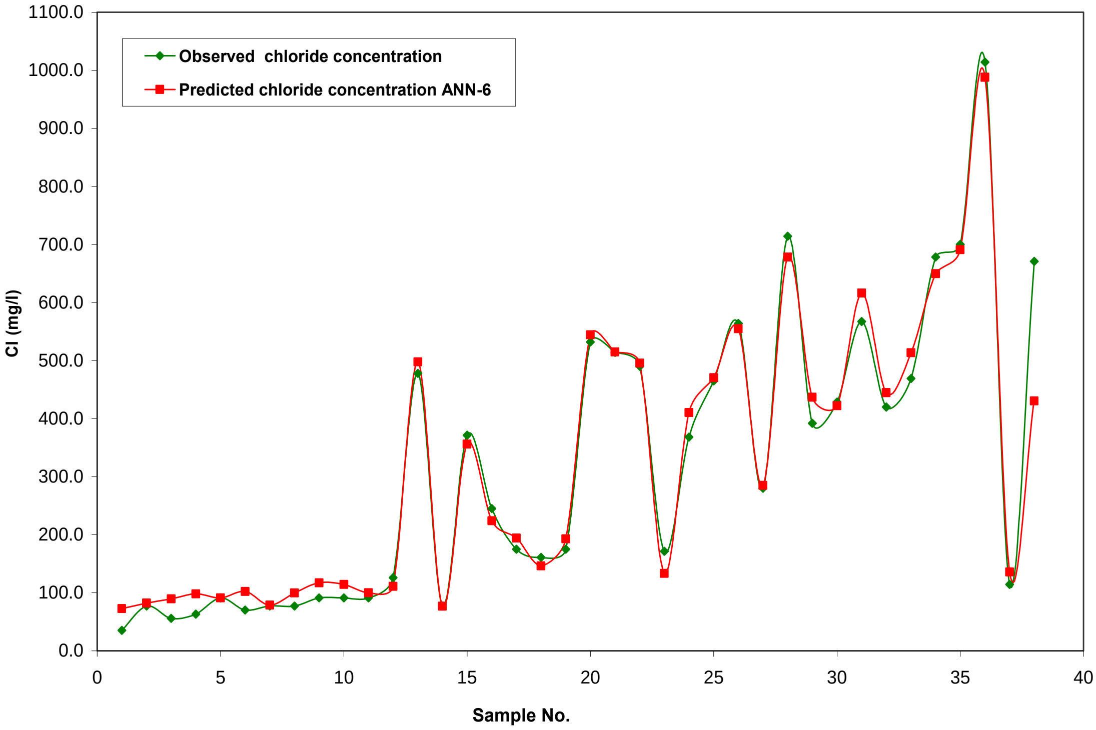


Figure (6.9): Comparison of simulated chloride concentration using ANN and the observed chloride concentration on 1/10/2000

6.3.3 Summary Regression Statistics of Final ANN Model

It was noted that the values of regression statistics for the ANN model which presented in Table (6.5) referred that performance of ANN model was excellent as follows:

- Low value of **Error Mean**, **Abs E. Mean** and **S.D. Ratio** showed that the error between observed and simulated chloride concentration values using the ANN model are small.
- High value of **correlation coefficient (r)** showed that the simulated chloride concentration values using the ANN model are in good agreement with the observed chloride concentration.
- By comparing regression summary statistics of final an ANN model (using **MLP** with 6 inputs) and initial ANN model (RBF with 9 inputs), it was concluded that the performance of final ANN model is better than the performance of final ANN model.

Table (6.5): The values of regression statistics for final ANN model

Regression statistics	All model data	Training data set	Validation data set	Test data set
Data Mean	341.105	295.877	345.200	361.427
Data S.D.	260.827	247.433	262.657	263.607
Error Mean	3.242	5.016	8.428	-0.196
Error S.D.	45.371	45.125	47.312	44.204
Abs E. Mean	29.798	29.262	32.128	28.911
S.D. Ratio	0.174	0.182	0.180	0.168
Correlation (r)	0.9848	0.9832	0.9837	0.9860

6.3.4 Sensitivity Analysis

Table (6.6) presented the value of error Ratio and Rank of input variables for the final ANN Model.

Table (6.6): The value of error ratio and rank of input variables

Variables	Cl_o	R	Q	Qr	Lt	Th
Error Ratio	**5.628**	**1.034**	**1.035**	**1.041**	**1.050**	**1.024**
Variables Rank	**1**	**5**	**4**	**3**	**2**	**6**
Training error ratio	5.858	1.023	1.045	1.055	1.044	1.041
Training variables Rank	1	6	3	2	4	5
Validation error ratio	5.375	1.074	1.040	1.058	1.061	1.026
Validation variables Rank	1	2	5	4	3	6
Test error ratio	5.450	1.008	1.010	0.995	1.049	0.988
Test variables Rank	1	4	3	5	2	6

It was noted that value of Error Ratio of the initial chloride concentration (Cl_o) is the highest value of Error Ratio which mean that the final Chloride concentration (Cl_f) is high correlated to initial chloride concentration (Cl_o). The most other important variables for this model is life time (Lt), abstraction average rate of area (Qr), abstraction (Q), recharge (R) and aquifer thickness (Th).

6.3.5 Response Presentations

Response presentations of final ANN model includes two types of figures, response graph and response surface.

6.3.5.1 Response Graph

Response graph shows the effect on the output variable prediction of adjusting input (independent) variables. The ANN model was utilized to study the influence of the input variables on output variable which is chloride concentration. Figure (6.10) presented a response graph of each input variables of final ANN model.

Figures (6.10.a,c,d,e) indicated that chloride concentration increases nonlinearly as chloride concentration initial, abstraction, abstraction average rate and life time increase. Figures (6.10.b,f) indicated that chloride concentration decreases nonlinearly as recharge rate and aquifer thickness increase. The detailed and comprehensive discussion about the variables and their effects are presented in section 6.3.6.

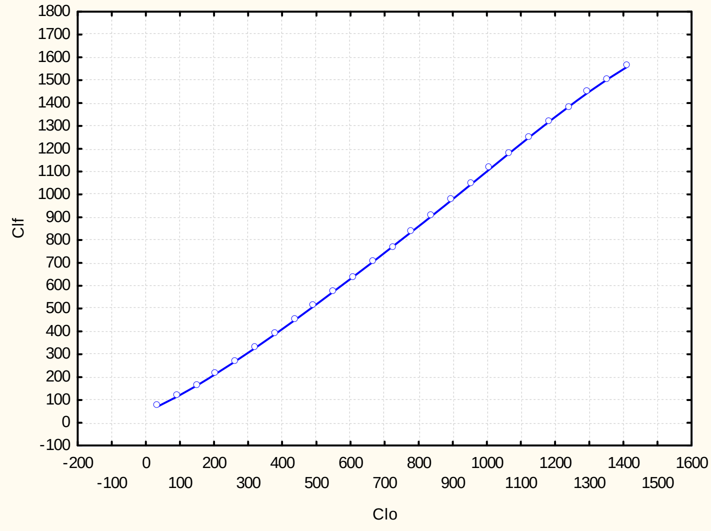


Figure (6.10.a): Response graph of Cl_o

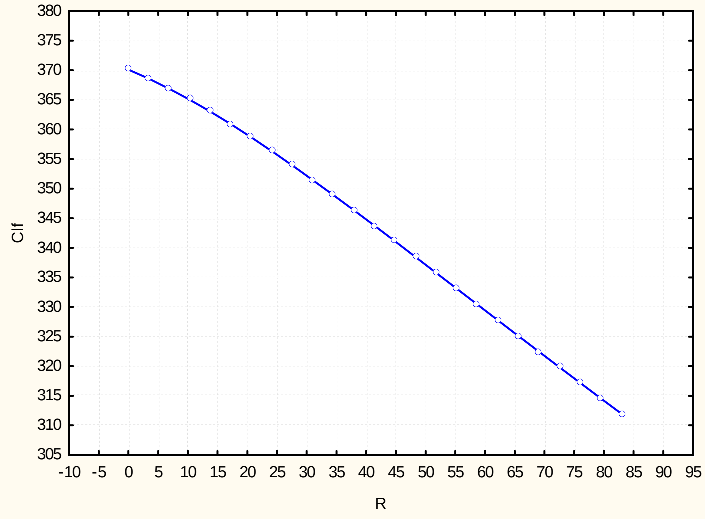


Figure (6.10.b): Response graph of R

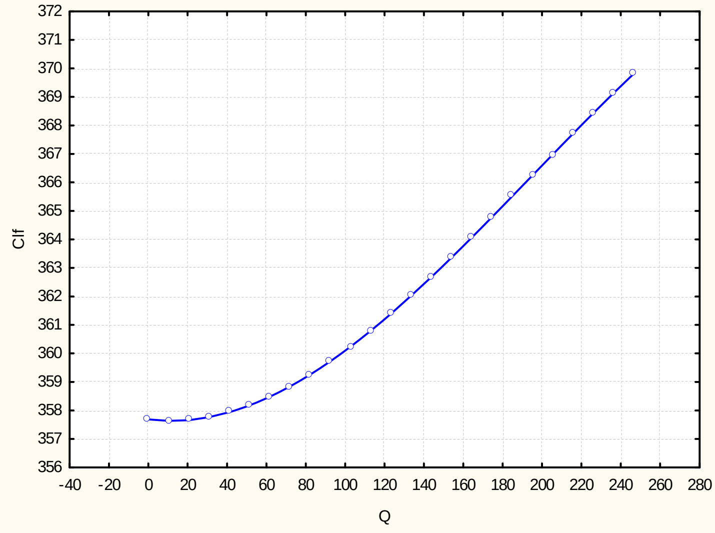


Figure (6.10.c): Response graph of Q

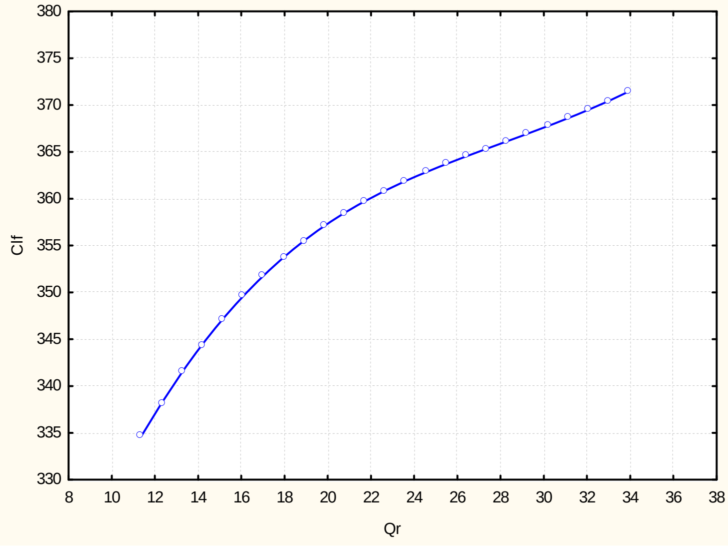


Figure (6.10.d): Response graph of Qr

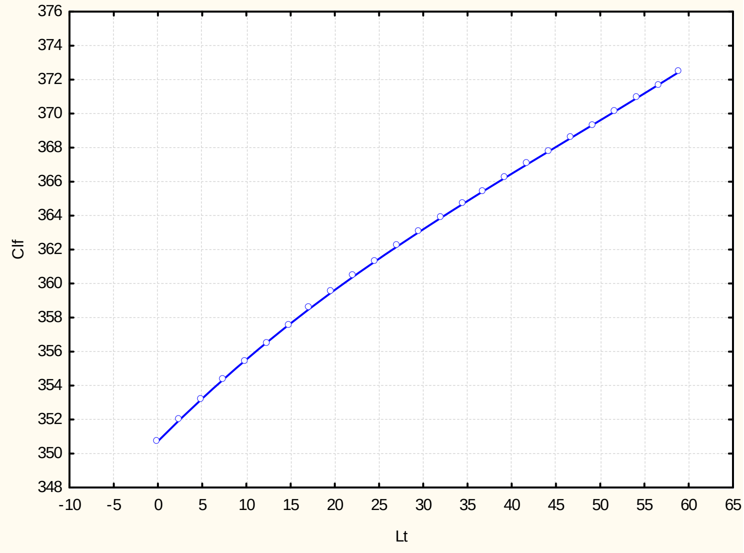


Figure (6.10.e): Response graph of Lt

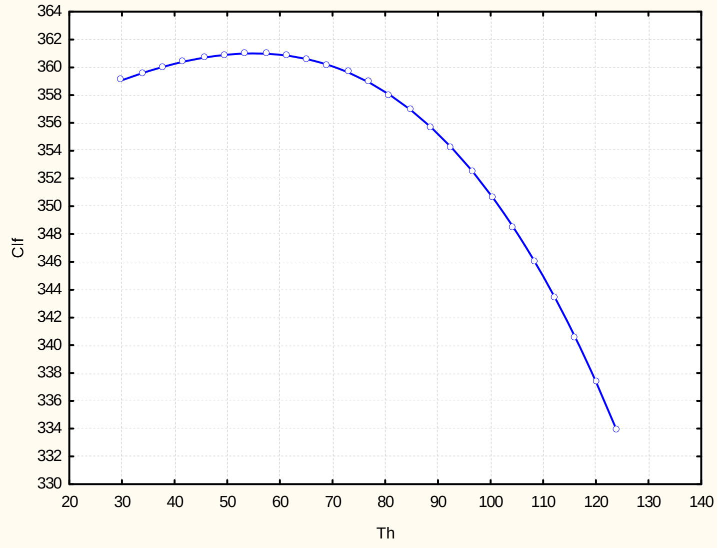


Figure (6.10.f): Response graph of Th

Figure (6.10) Response graph of each input variables of final ANN model

6.3.5.2 Response Surface

A response surface is a figure shows the effect on the output variable prediction of adjusting two input (independent) variables. The ANN model was utilized to study the influence of each two input variables on chloride concentration. Figures (6.11) presented response surface of each two input variables of final ANN model

Figures (6.11.a) indicated that the chloride concentration increases nonlinearly as recharge decreases and abstraction increases and the effect of recharge is stronger than effect of abstraction. Figure (6.11.b) indicated that the chloride concentration increases nonlinearly as recharge decreases and abstraction average rate increases and the effect of recharge is similar to effect of abstraction average rate. Figure (6.11.c) indicated that the chloride concentration increases nonlinearly as life time increases and recharge decreases and the effect of recharge is stronger than effect of life time. Figures (6.11.d) indicated that the chloride concentration increases nonlinearly as recharge decrease and aquifer thickness and the effect of aquifer thickness is stronger than effect of recharge.

Figure (6.11.e) indicated that the chloride concentration increases nonlinearly as abstraction and abstraction average rate increase and the effect of abstraction average rate is similar to the effect of abstraction. Figure (6.11.f) indicated that the chloride concentration increases nonlinearly as abstraction and life time increase and the effect of life time is similar to effect of abstraction. Figure (6.11.g) indicated that the chloride concentration increases nonlinearly as abstraction increases and aquifer thickness decrease. In addition, it was noted that effect of aquifer thickness is stronger than effect of abstraction.

Figure (6.11.h) indicated that the chloride concentration increases nonlinearly as abstraction average rate and life time increase and the effect of abstraction average rate is stronger than effect of life time. Figure (6.11.i) indicated that the chloride concentration increases nonlinearly as abstraction average rate increases and aquifer thickness decreases and the effect of aquifer thickness is similar to effect of abstraction average rate.

Figure (6.11.j) indicated that the chloride concentration increases nonlinearly as life time increases and aquifer thickness decreases. In addition, it was noted that effect of aquifer thickness is similar to effect of life time.

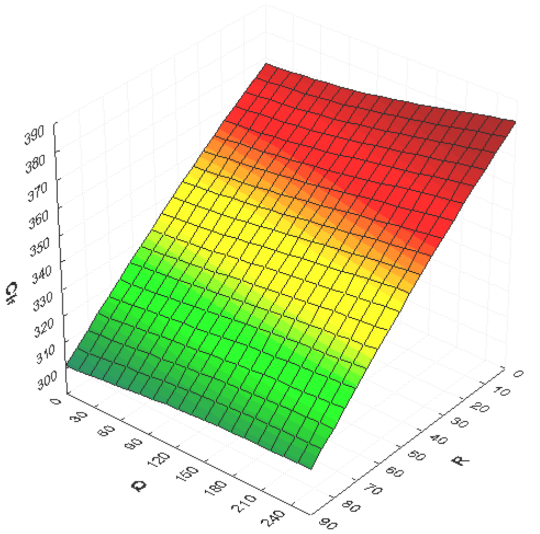


Figure (6.11.a) Response surface of R & Q

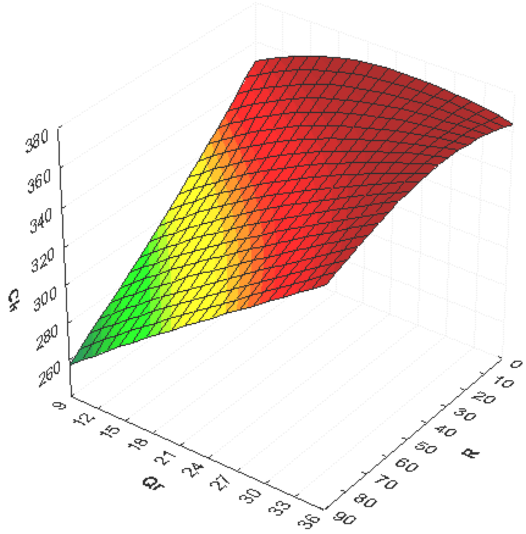


Figure (6.11.b) Response surface of R & Qr

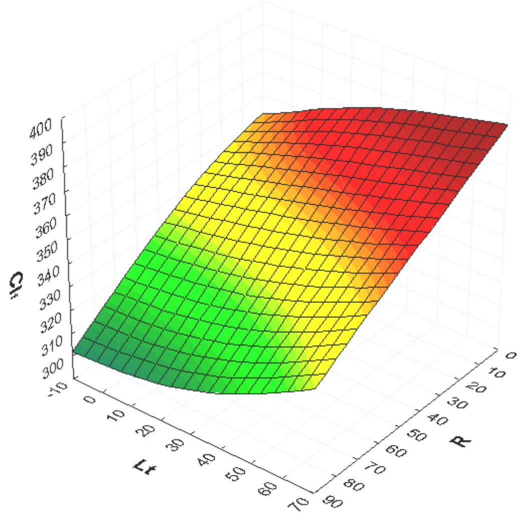


Figure (6.11.c) Response surface of R & Lt

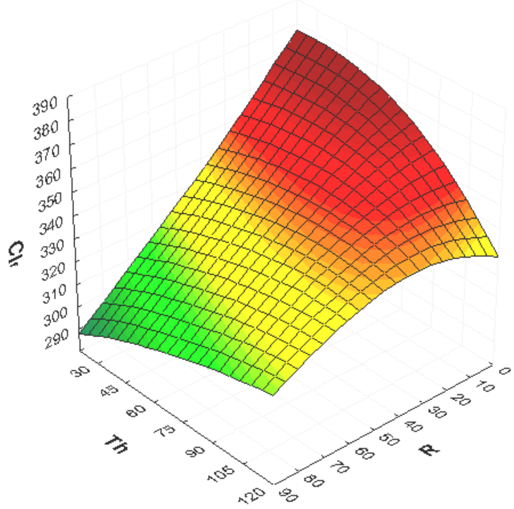


Figure (6.11.d) Response surface of R & Th

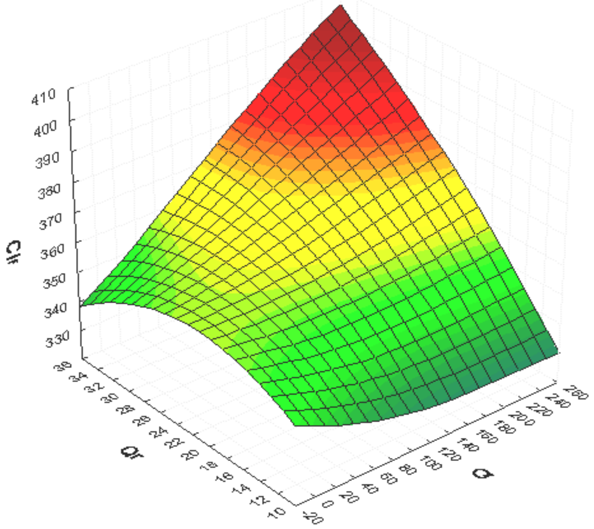


Figure (6.11.e) Response surface of Q & Qr

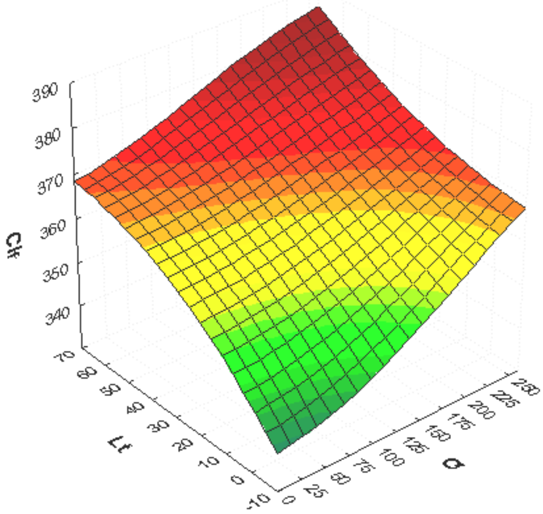


Figure (6.11.f) Response surface of Q & Lt

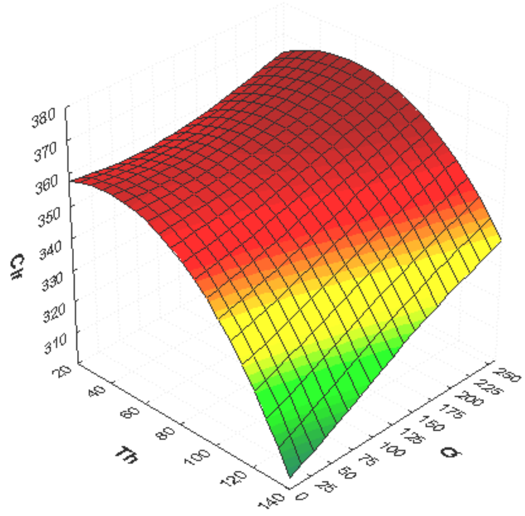


Figure (6.11.g) Response surface of Q & Th

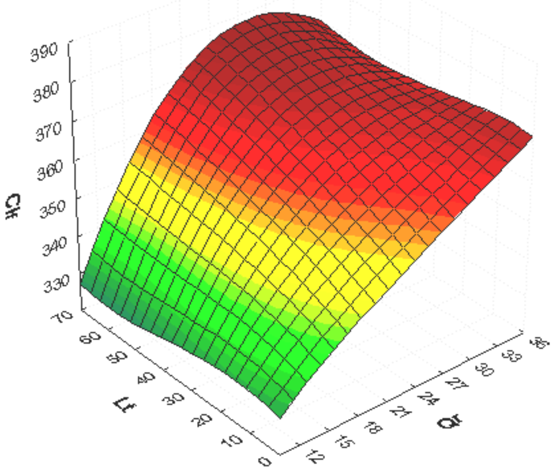


Figure (6.11.h) Response surface of Qr & Lt

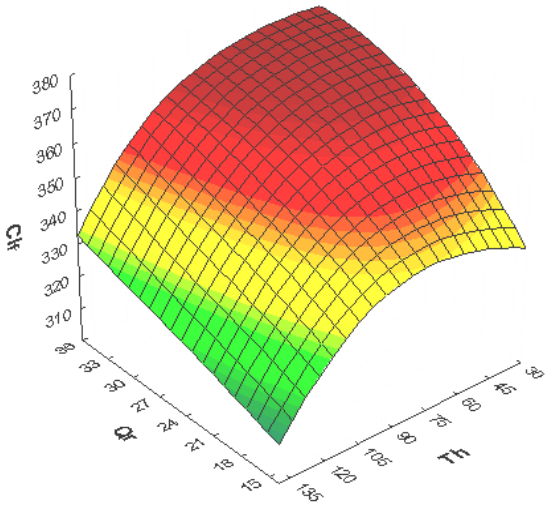


Figure (6.11.i) Response surface of Th & Qr

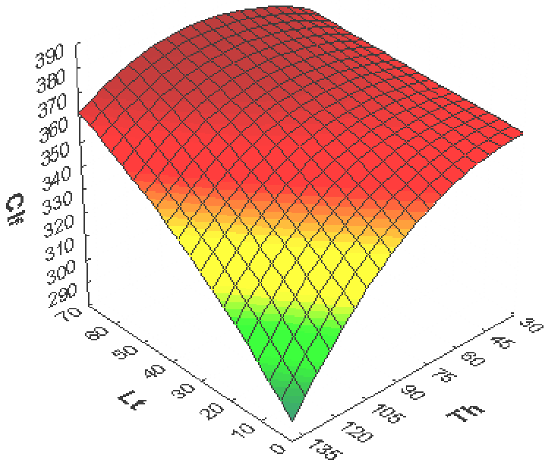


Figure (6.11.j) Response surface of Th & Lt

Figures (6.11) Response surface of each two input variables of final ANN model

6.4 Application of ANN Model

The ANN model was utilized in many practical and theoretical applications. It was utilized as analytical tool to study the influence of the input variables on chloride concentration. Furthermore, it was utilized as simulation and prediction tool of chloride concentration on domestic wells in Gaza Strip. Finally it was utilized as a decision making support tool.

6.4.1 Utilizing ANN Model as Analytical Tool

The ANN model was utilized to study the influence of the input variables on chloride concentration. Hypothetical cases of input variables were assumed to study the influence of the input variables. Three level of confidence were assumed: the first one was consolidating the values of input variables on the mean value and changing the value of studied variable gradually from minimum value to maximum value in the range of input variable.

The second level of confidence was consolidating the values of abstraction, abstraction average rate and life time on the mean plus the value of standard deviation. In addition it was consolidating the values of recharge rate and aquifer thickness on the mean subtract the value of standard deviation which produce conditions lead to increase chloride concentration in groundwater.

The third level of confidence was consolidating the values of abstraction, abstraction average rate and life time on the mean subtract the value of standard deviation and consolidating the values of recharge rate and aquifer thickness on the mean plus the value of standard deviation which produce conditions lead to decrease chloride concentration in groundwater.

To obtain the values of gradual changing for input variable from minimum value to maximum value in the range of input variable, the range was divided to ten steps and the value gradually was increased from minimum value to maximum value in the range. Table (6.7) presented the hypothetical values of gradual change of input variables. Hypothetical values of input variables for the three analysis conditions were computed as explained above and they were presented in Table (6.7).

Table (6.7): Hypothetical values of gradual change for input variables

	Cl_o	**R**	**Q**	**Qr**	**Lt**	**Th**
Unit	**mg/l**	**$mm/m^2/month$**	**$m^3/hour$**	**$mm/m^2/month$**	**y**	**m**
Min.	**28.00**	**0.00**	**0.00**	**11.37**	**0.00**	**30.00**
Max.	**1412.00**	**83.07**	**254.94**	**33.94**	**60.00**	**124.00**
1	330.00	0.00	0.00	12.00	0.00	30.00
2	330.00	8.00	25.00	14.30	6.00	39.00
3	330.00	16.00	50.00	16.60	12.00	48.00
4	330.00	24.00	75.00	18.90	18.00	57.00
5	330.00	32.00	100.00	21.20	24.00	66.00
6	330.00	40.00	125.00	23.50	30.00	75.00
7	330.00	48.00	150.00	25.80	36.00	84.00
8	330.00	56.00	175.00	28.10	42.00	93.00
9	330.00	64.00	200.00	30.40	48.00	102.00
10	330.00	72.00	225.00	32.70	54.00	111.00
11	330.00	80.00	250.00	35.00	60.00	120.00

Table (6.8): Hypothetical values of input variables for the three analysis conditions

	Cl_o	R	Q	Qr	Lt	Th
Min.	28.00	0.00	0.00	11.37	0.00	30.00
Max.	1412.00	83.07	254.94	33.94	60.00	124.00
Mean	333.07	18.19	105.55	22.50	22.02	64.17
S.D	253.94	24.44	57.99	5.80	13.94	27.25
M+S.D	587.01	42.64	163.54	28.30	35.95	91.41
M-S.D	79.13	-6.25	47.56	16.70	8.08	36.92
Normal Condition	330.00	18.00	105.00	22.00	22.00	65.00
Decreasing Condition	330.00	0.00	164.00	29.00	36.00	40.00
Increasing Condition	330.00	43.00	47.00	16.00	8.00	91.00

6.4.1.1 Influence of Recharge Rate on Chloride Concentration

By application the above mentioned procedure and using the final ANN model to calculate the value of final chloride concentration for each hypothetical case, the effect of recharge rate on chloride concentration was studied. Results of the three conditions (normal, increasing and decreasing) were presented in Figure (6.12) and Table (6.9) and Table (6.10).

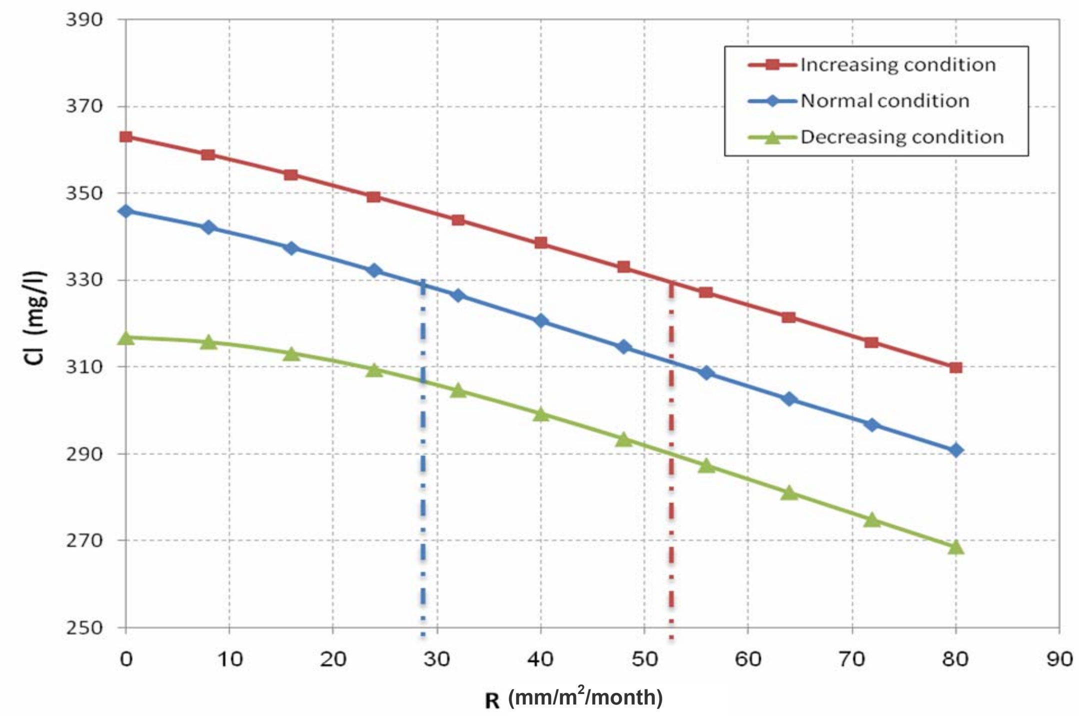


Fig (6.12): Impact of recharge rate on chloride concentration

Table (6.9): Results of ANN model for hypothetical cases studied the effect of recharge rate on chloride concentration

Normal Condition							
	Clo	**R**	**Q**	**Qr**	**Lt**	**Th**	**Cl_f**
1	330.00	**0.00**	105.00	22.00	22.00	65.00	**346.00**
2	330.00	**8.00**	105.00	22.00	22.00	65.00	**342.11**
3	330.00	**16.00**	105.00	22.00	22.00	65.00	**337.45**
4	330.00	**24.00**	105.00	22.00	22.00	65.00	**332.21**
5	330.00	**32.00**	105.00	22.00	22.00	65.00	**326.58**
6	330.00	**40.00**	105.00	22.00	22.00	65.00	**320.70**
7	330.00	**48.00**	105.00	22.00	22.00	65.00	**314.71**
8	330.00	**56.00**	105.00	22.00	22.00	65.00	**308.67**
9	330.00	**64.00**	105.00	22.00	22.00	65.00	**302.67**
10	330.00	**72.00**	105.00	22.00	22.00	65.00	**296.75**
11	330.00	**80.00**	105.00	22.00	22.00	65.00	**290.91**
Increasing Condition							
	Clo	**R**	**Q**	**Qr**	**Lt**	**Th**	**Cl_f**
1	330.00	**0.00**	164.00	29.00	36.00	40.00	**363.06**
2	330.00	**8.00**	164.00	29.00	36.00	40.00	**358.88**
3	330.00	**16.00**	164.00	29.00	36.00	40.00	**354.22**
4	330.00	**24.00**	164.00	29.00	36.00	40.00	**349.20**
5	330.00	**32.00**	164.00	29.00	36.00	40.00	**343.91**
6	330.00	**40.00**	164.00	29.00	36.00	40.00	**338.45**
7	330.00	**48.00**	164.00	29.00	36.00	40.00	**332.86**
8	330.00	**56.00**	164.00	29.00	36.00	40.00	**327.19**
9	330.00	**64.00**	164.00	29.00	36.00	40.00	**321.47**
10	330.00	**72.00**	164.00	29.00	36.00	40.00	**315.71**
11	330.00	**80.00**	164.00	29.00	36.00	40.00	**309.93**
Decreasing Condition							
	Clo	**R**	**Q**	**Qr**	**Lt**	**Th**	**Cl_f**
1	330.00	**0.00**	47.00	16.00	8.00	91.00	**316.89**
2	330.00	**8.00**	47.00	16.00	8.00	91.00	**315.78**
3	330.00	**16.00**	47.00	16.00	8.00	91.00	**313.21**
4	330.00	**24.00**	47.00	16.00	8.00	91.00	**309.44**
5	330.00	**32.00**	47.00	16.00	8.00	91.00	**304.73**
6	330.00	**40.00**	47.00	16.00	8.00	91.00	**299.33**
7	330.00	**48.00**	47.00	16.00	8.00	91.00	**293.47**
8	330.00	**56.00**	47.00	16.00	8.00	91.00	**287.35**
9	330.00	**64.00**	47.00	16.00	8.00	91.00	**281.12**
10	330.00	**72.00**	47.00	16.00	8.00	91.00	**274.89**
11	330.00	**80.00**	47.00	16.00	8.00	91.00	**268.75**

Table (6.10): Summary of results of ANN model for hypothetical cases studied the effect of recharge rate on chloride concentration

	R	Cl_f	Cl_f	Cl_f
		Decreasing	**Normal**	**Increasing**
1	**0.00**	316.89	346.00	363.06
2	**8.00**	315.78	342.11	358.88
3	**16.00**	313.21	337.45	354.22
4	**24.00**	309.44	332.21	349.20
5	**32.00**	304.73	326.58	343.91
6	**40.00**	299.33	320.70	338.45
7	**48.00**	293.47	314.71	332.86
8	**56.00**	287.35	308.67	327.19
9	**64.00**	281.12	302.67	321.47
10	**72.00**	274.89	296.75	315.71
11	**80.00**	268.75	290.91	309.93

It was noted that increasing recharge rate from 0 to 80 mm/m^2/month resulted in a large influence in final chloride concentration as follows:

- In **normal condition**, when the initial chloride concentration = 330 mg/l , abstraction =105 m^3/hr, abstraction average rate = 22 mm/m^2/month, life time = 22 years and aquifer thickness = 65 m. Final chloride concentration decrease from 346.00 mg/l to 290.91 mg/l. Final chloride concentration stayed stable of 330 mg/l on recharge rate of 28 mm/month.
- In **increasing condition**, when the initial chloride concentration = 330 mg/l , abstraction =146 m3/hr, abstraction average rate = 29 mm/m^2/month, life time = 36 years and aquifer thickness = 40 m. Final chloride concentration decreased from 363.06 mg/l to 309.93 mg/l. Final chloride concentration stayed stable of 330 mg/l on recharge rate of 52 mm/ m^2/month.
- In **decreasing condition**, when initial chloride concentration = 330 mg/l, abstraction = 47 m3/hr, abstraction average rate = 16 mm/m^2/month, Life time = 8 years and aquifer thickness = 91 m. Final chloride concentration decreased from 316.89 mg/l to 268.75 mg/l. In this condition final chloride concentration stayed less than 330 mg/l for all values of recharge rate even if small values of recharge because of very good condition of small value of abstraction, abstraction average rate life time and large aquifer thickness.
- It is noted that stabilization point of chloride concentration for normal condition occurred at recharge rate = 22 mm/m^2/month and for increasing condition occurs at recharge rate = 52 mm/m^2/month which mean that increasing condition required height recharge rate to achieve stabilization point of chloride concentration. In decreasing condition final chloride concentration stayed less

than 330 mg/l with values 316.89 mg/l to 268.75 mg/l for all values of recharge rate even if small values of recharge rate were available.

6.4.1.2 Influence of Abstraction on Chloride Concentration

By application the above mentioned procedure and using the final ANN model to calculate the value of final chloride concentration for each hypothetical case, the effect of abstraction on chloride concentration was studied. Results of the three conditions (normal, increasing and decreasing) were presented in Figure (6.13) and Table (6.11).

Results of ANN model for hypothetical cases studied the effect of abstraction on chloride concentration are presented in Annex 7.

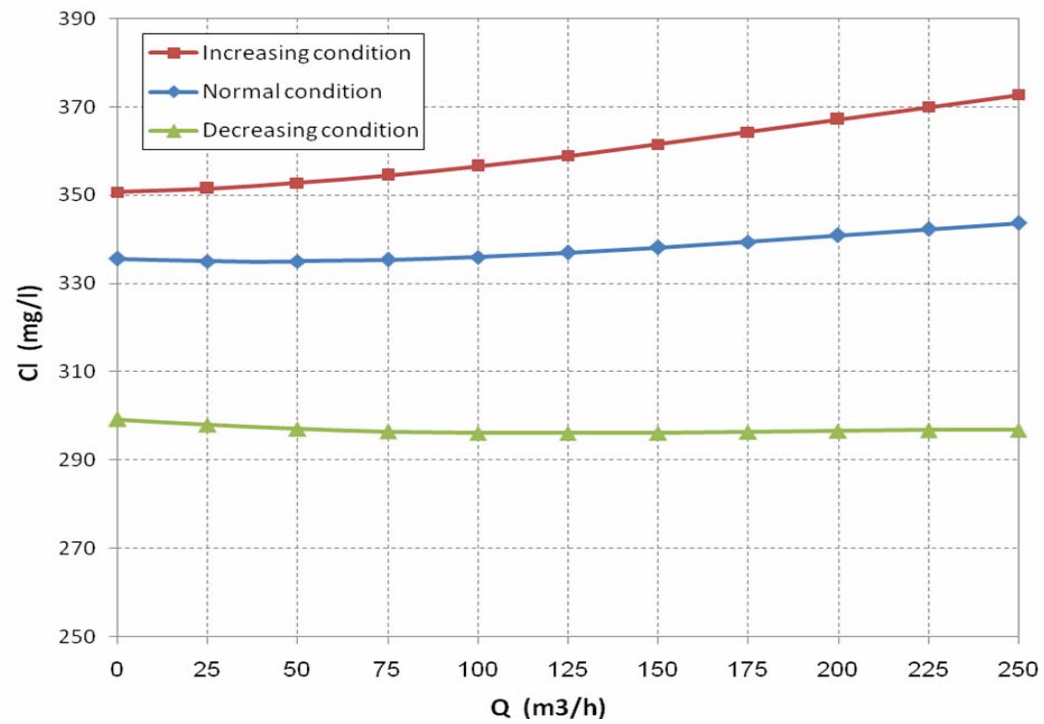


Fig (6.13): Effect of abstraction on chloride concentration

Table (6.11): Results of ANN model for hypothetical cases studied the effect of abstraction on chloride concentration

	Q	**Cl_f**	**Cl_f**	**Cl_f**
		Decreasing	**Normal**	**Increasing**
1	**0.00**	299.29	335.6	350.68
2	**25.00**	298.00	335.1	351.47
3	**50.00**	297.08	335.0	352.75
4	**75.00**	296.49	335.4	354.47

5	**100.00**	296.19	336.0	356.55
6	**125.00**	296.11	337.0	358.93
7	**150.00**	296.20	338.1	361.53
8	**175.00**	296.39	339.5	364.29
9	**200.00**	296.61	340.9	367.13
10	**225.00**	296.78	342.3	369.97
11	**250.00**	296.83	343.7	372.74

It was noted that increasing abstraction from 0 to 250 m^3/hr results in a small influence in final chloride concentration as follows:

- In **normal condition**, when the initial chloride concentration = 330 mg/l, recharge rate = 18 mm/m^2/month, abstraction average rate = 22 mm/m^2/month, life time = 22 years and aquifer thickness = 65 m. Final chloride concentration increases from **335.6** mg/l to **343.7** mg/l. Final chloride concentration stays more than 330 mg/l for all values of abstraction.
- In **increasing condition**, when the initial chloride concentration = 330 mg/l , recharge rate = 0 mm/ m^2/month, abstraction average rate = 29 mm/m^2/month, life time = 36 years and aquifer thickness = 40 m. Final chloride concentration decrease from **350.68** mg/l to **372.74** mg/l. Final chloride concentration stays more than 330 mg/l for all values of abstraction.
- In **decreasing condition**, when the initial chloride concentration = 330 mg/l, recharge rate = 43 mm/m^2/month, Abstraction average rate = 16 mm/m^2/month, life time = 8 years and aquifer thickness = 91 m. Final chloride concentration Stays almost steady at **297** mg/l which mean that in good condition of small value of Abstraction average rate and life time and large value of Recharge rate and aquifer thickness, Increasing abstraction dos not affect on the chloride concentration and it decreases about 33 mg/l which is good result.

6.4.1.3 Impacts of Abstraction Average Rate on Chloride Concentration

By application the above mentioned procedure and using the final ANN model to calculate the value of final chloride concentration for each hypothetical case, the effect of abstraction average rate on chloride concentration was studied. Results of the three conditions (normal, increasing and decreasing) were presented in Figure (6.14) and Table (6.12).

Results of ANN model for hypothetical cases studied the effect of abstraction average rate on chloride concentration are presented in Annex 7.

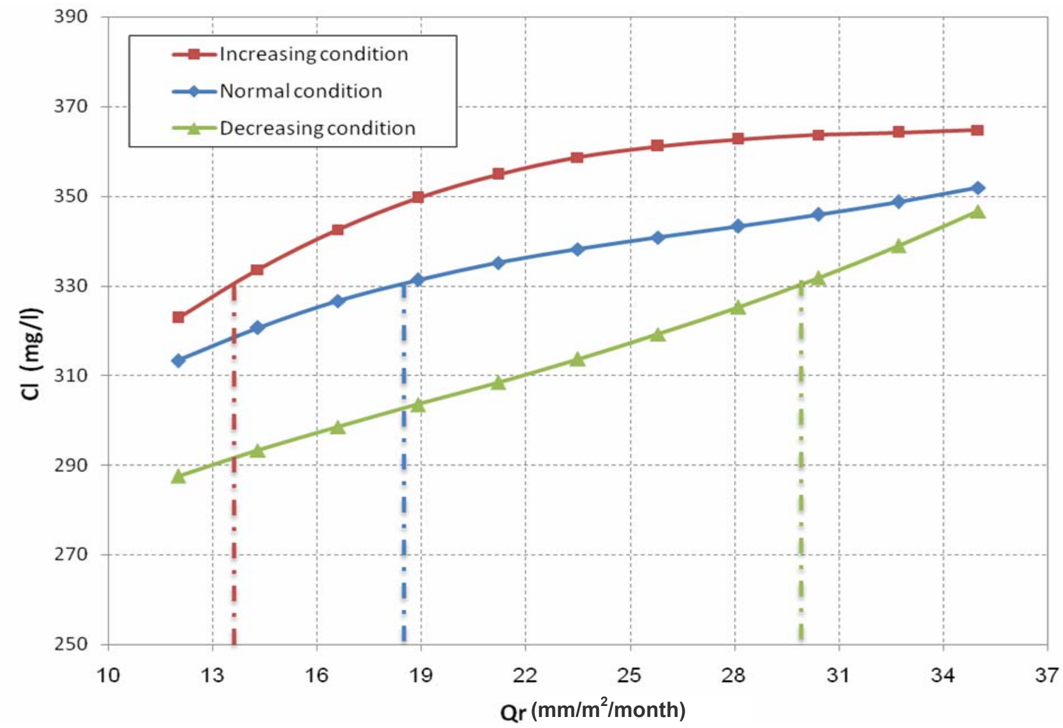


Fig (6.14): Effect of abstraction average rate on chloride concentration

Table (6.12): Results of ANN model for hypothetical cases studied the effect of abstraction average rate on chloride concentration

	Qr	Cl_f	Cl_f	Cl_f
		Decreasing	**Normal**	**Increasing**
1	**12.00**	287.56	313.29	322.78
2	**14.30**	293.28	320.67	333.63
3	**16.60**	298.50	326.61	342.53
4	**18.90**	303.48	331.32	349.55
5	**21.20**	308.46	335.06	354.83
6	**23.50**	313.64	338.11	358.58
7	**25.80**	319.18	340.75	361.08
8	**28.10**	325.20	343.25	362.64
9	**30.40**	331.77	345.82	363.57
10	**32.70**	338.91	348.66	364.16
11	**35.00**	346.61	351.91	364.68

It was noted that increasing abstraction average rate from 12 to 35 mm/m^2/month results in a large influence in final chloride concentration as follows:

- In **normal condition**, when the initial chloride concentration = 330 mg/l , recharge rate = 18 mm/ m^2/month, abstraction =105 m^3/hr, life time = 22 years and aquifer thickness = 65 m. Final chloride concentration increases from **313.29** mg/l to **351.91** mg/l. Final chloride concentration stays stable and = 330 mg/l on Abstraction average rate = 18.5 mm/m^2/month.
- In **increasing condition**, when the initial chloride concentration = 330 mg/l , recharge rate = 0 mm/m^2/month, abstraction =164 m^3/hr, life time = 36 years and aquifer thickness = 40 m. Final chloride concentration increases from **322.78** mg/l to **364.68** mg/l. Final chloride concentration stays stable and = 330 mg/l on abstraction average rate = 14 mm/m^2/month
- In **decreasing condition**, when the initial chloride concentration = 330 mg/l, recharge rate = 43 mm/m^2/month, abstraction = 47 m^3/hr, Life time = 8 years and aquifer thickness = 91. Final chloride concentration increases from **287.56** mg/l to **346.61** mg/l. Final chloride concentration stays stable and = 330 mg/l on abstraction average rate = 30 mm/m^2/month.
- It is noted that stabilization point of chloride concentration for normal condition occurs at abstraction average rate = 18.5 mm/m^2/month and for increasing condition occurs at abstraction average rate = 14 mm/m^2/month and for decreasing condition occurs at abstraction average rate = 30 mm/m^2/month which mean that increasing condition requires smallest abstraction average rate to achieve stabilization point of chloride concentration while decreasing condition can achieve stabilization point of chloride concentration with height value of abstraction average rate.

6.4.1.4 Influence of Life Time on Chloride Concentration

By application the above mentioned procedure and using the final ANN model to calculate the value of final chloride concentration for each hypothetical case, the effect of life time on chloride concentration was studied. Results of the three conditions (normal, increasing and decreasing) were presented in Figure (6.15) and Table (6.13).

Results of ANN model for hypothetical cases studied the effect of life time on chloride concentration are presented in Annex 7.

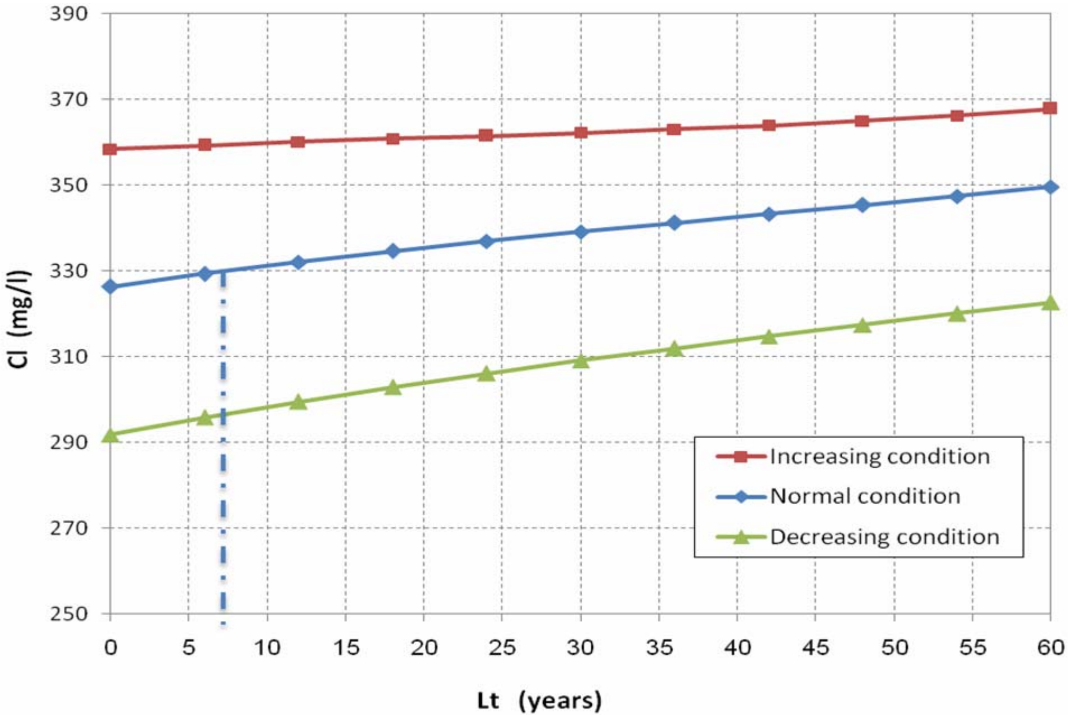


Fig (6.15): Effect of life time on chloride concentration

Table (6.13): Results of ANN model for hypothetical cases studied the effect of life time on chloride concentration

	Lt	Cl_f	Cl_f	Cl_f
		Decreasing	**Normal**	**Increasing**
1	**0.00**	291.91	326.36	358.44
2	**6.00**	295.91	329.36	359.32
3	**12.00**	299.60	332.10	360.10
4	**18.00**	303.00	334.61	360.82
5	**24.00**	306.18	336.95	361.53
6	**30.00**	309.17	339.15	362.26
7	**36.00**	312.02	341.26	363.06
8	**42.00**	314.76	343.33	363.97
9	**48.00**	317.44	345.40	365.04
10	**54.00**	320.09	347.50	366.30
11	**60.00**	322.75	349.67	367.78

It was noted that increasing Life time from 0 to 60 year results in a large influence in final chloride concentration as follows:

- In **normal condition**, when the initial chloride concentration = 330 mg/l , recharge rate = 18 mm/m^2/month, abstraction =105 m^3/hr, abstraction average rate = 22 mm/m^2/month, and aquifer thickness = 65 m. Final chloride concentration increases from **326.36** mg/l to **349.67** mg/l. final chloride concentration stays stable and = 330 mg/l on life time = 7 years.
- In **increasing condition**, when the initial chloride concentration = 330 mg/l , recharge rate = 0 mm/m^2/month, abstraction =164 m^3/hr, abstraction average rate = 29 mm/m^2/month and aquifer thickness = 40 m. Final chloride concentration increases from **358.44** mg/l to **367.78** mg/l. Final Chloride concentration stays more than 330 mg/l for all values of life time.
- In **decreasing condition**, when the initial chloride concentration = 330 mg/l, Recharge rate = 43 mm/m^2/month, Abstraction = 47 m3/hr, abstraction average rate = 16 mm/m2/month and aquifer thickness = 91. Final chloride concentration increases from **291.91** mg/l to **322.75** mg/l. Final chloride concentration stays less than 330 mg/l for all values of life time.
- It is noted that stabilization point of chloride concentration for normal condition occurs at life time = 6 year. For increasing condition, chloride concentration stays more than 330 mg/l with values from 358.44 mg/l to 367.78 mg/l and for decreasing condition final chloride concentration stay less than 330 mg/l from 291.91 mg/l to 322.75 which mean that increasing condition can not be achieve stabilization point of chloride concentration with all values of life time while as decreasing condition was expected to achieve stabilization point of chloride concentration with life time 70 year.

6.4.1.5 Influence of Aquifer Thickness on Chloride Concentration

By application the above mentioned procedure and using the final ANN model to calculate the value of final chloride concentration for each hypothetical case, the effect of aquifer thickness on chloride concentration was studied. Results of the three conditions (normal, increasing and decreasing) were presented in Figure (6.16) and Table (6.14).

Results of ANN model for hypothetical cases studied the effect of aquifer thickness on chloride concentration are presented in Annex 7.

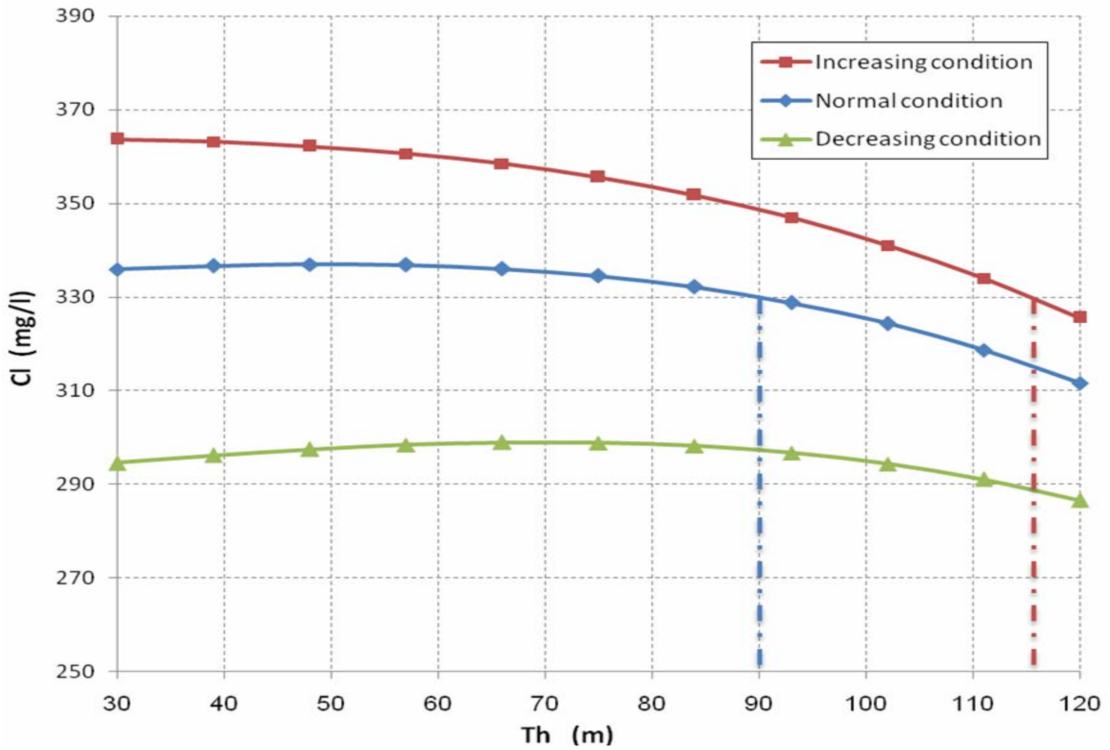


Fig (6.16): Effect of aquifer thickness on chloride concentration

Table (6.14): Results of ANN model for hypothetical cases studied the effect of aquifer thickness on chloride concentration

	Lt	Cl_f	Cl_f	Cl_f
	Year	**Decreasing**	**Normal**	**Increasing**
1	**30.00**	294.57	335.91	363.70
2	**39.00**	296.17	336.66	363.15
3	**48.00**	297.48	337.00	362.17
4	**57.00**	298.44	336.84	360.66
5	**66.00**	298.95	336.07	358.51
6	**75.00**	298.91	334.56	355.60
7	**84.00**	298.23	332.19	351.79
8	**93.00**	296.78	328.84	346.99
9	**102.00**	294.45	324.39	341.08
10	**111.00**	291.11	318.70	333.96
11	**120.00**	286.65	311.69	325.57

It was noted that increasing aquifer thickness from 30 to 120 mm/m2/month results in a large influence in final chloride concentration as follows:

- In **normal condition**, when the initial chloride concentration = 330 mg/l , Recharge rate = 18 mm/m^2/month, abstraction =105 m^3/hr, abstraction average rate = 22 mm/m^2/month and life time = 22 years. Final chloride concentration decrease from **335.91** mg/l to **311.69** mg/l. Final chloride concentration stays stable and = 330 mg/l on aquifer thickness = 90 m.
- In **increasing condition**, when the initial chloride concentration = 330 mg/l , recharge rate = 0 mm/m^2/month, Abstraction =146 m^3/hr, abstraction average rate = 29 mm/m^2/month and life time = 36 years. Final chloride concentration decreases from **363.70** mg/l to **325.57** mg/l. Final chloride concentration stays stable and = 330 mg/l on aquifer thickness = 115 m.
- In **decreasing condition**, when the initial chloride concentration = 330 mg/l, recharge rate = 43 mm/m^2/month, abstraction = 47 m^3/hr, abstraction average rate = 16 mm/m^2/month and life time = 8 years. Final chloride concentration decrease from **294.57** mg/l to **286.65** mg/l. In this condition final chloride concentration stays less than 330 mg/l for all values of aquifer thickness even if small values of aquifer thickness because of very good condition of small value of abstraction, abstraction average rate and life time and large value of recharge rate.
- It is noted that stabilization point of chloride concentration for normal condition occurs at aquifer thickness = 90 m and for increasing condition occurs at aquifer thickness = 115 m which mean that increasing condition requires height aquifer thickness to achieve stabilization point of chloride concentration. In decreasing condition final chloride concentration stays less than 330 mg/l with values from 294.57 mg/l to 286.65 mg/l for all values of aquifer thickness even if small values of aquifer thickness.

6.4.2 Utilizing ANN Model as a Simulation Tool

The ANN model was utilized to simulate chloride concentration in some domestic wells in Gaza Strip for the years exist in the time range of ANN model. Contour map of chloride concentration of pumped groundwater was prepared for ANN simulated results. Another contour map of observed chloride concentration of pumped groundwater was prepared in order to compare between the observed and simulated values of chloride concentration. These steps were prepared for October, 1997 and October, 2001. Figures (6.17), (6.18), (6.19) and (6.20) presented the observed and simulated chloride concentration of pumped groundwater in Gaza Strip in October, 1997 and October, 2001. The figures show high degree of similarity between the simulated and the observed contour maps. The chloride concentration data of study wells for October, 1997 and October, 2001 are represented in Annex 1.

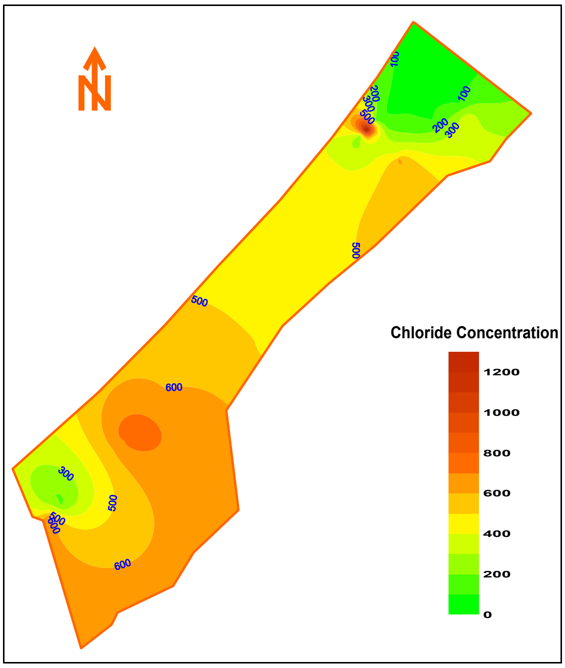


Figure (6.17): Observed chloride concentration of pumped groundwater in Gaza Strip (October, 1997)

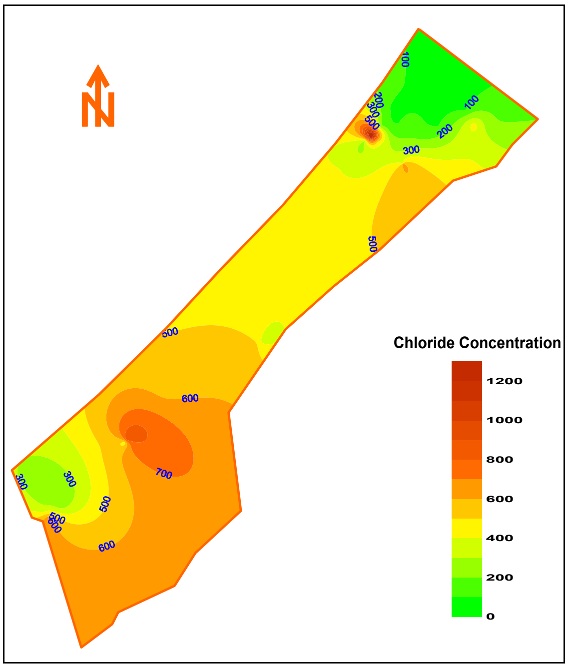


Figure (6.18): Simulated chloride concentration of pumped groundwater in Gaza Strip (October, 1997)

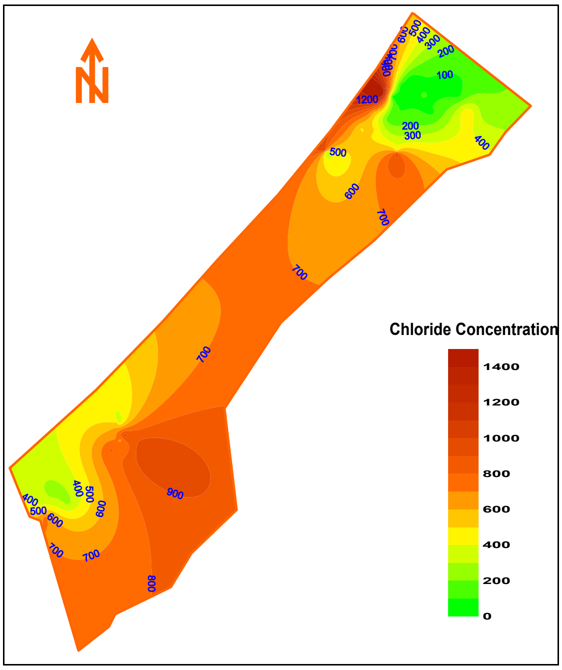


Figure (6.19): Observed chloride concentration of pumped groundwater in Gaza Strip (October, 1997)

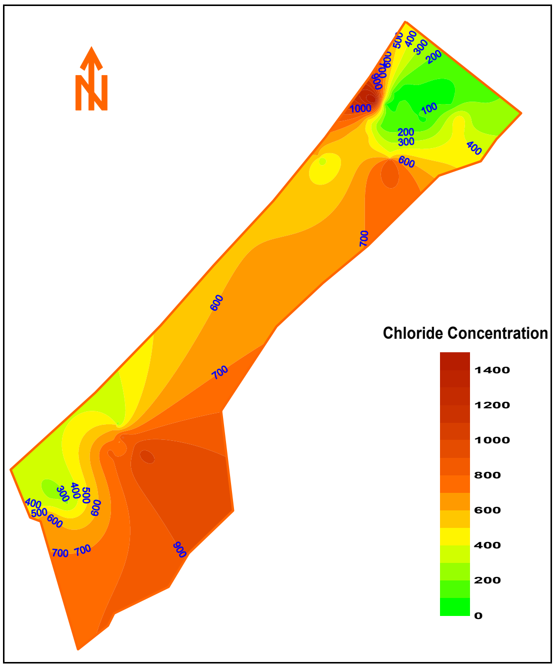


Figure (6.20): Simulated chloride concentration of pumped groundwater in Gaza Strip (October, 2001)

6.4.3 Utilizing ANN Model as a Prediction Tool

The ANN model was utilized to predict chloride concentration in some domestic wells in Gaza Strip for the years do not exist in the time range of ANN model. Contour map of chloride concentration of pumped groundwater was prepared for ANN predicted results. Another contour map of observed chloride concentration of pumped groundwater was prepared in order to compare between the observed and simulated values of chloride concentration. These steps were prepared for October, 2007. Figures (6.21) and (6.22) presented the observed and predicted chloride concentration of pumped groundwater in Gaza Strip in October, 2007. The figures show high degree of similarity between the predicted and the observed contour maps. The chloride concentration data of study wells for October, 2007 are represented in Annex 8.

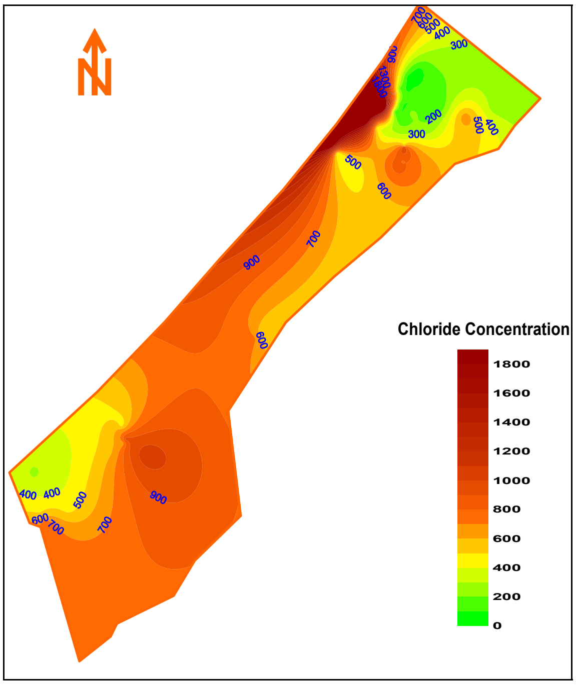


Figure (6.21): Observed chloride concentration of pumped groundwater in Gaza Strip (October, 2007)

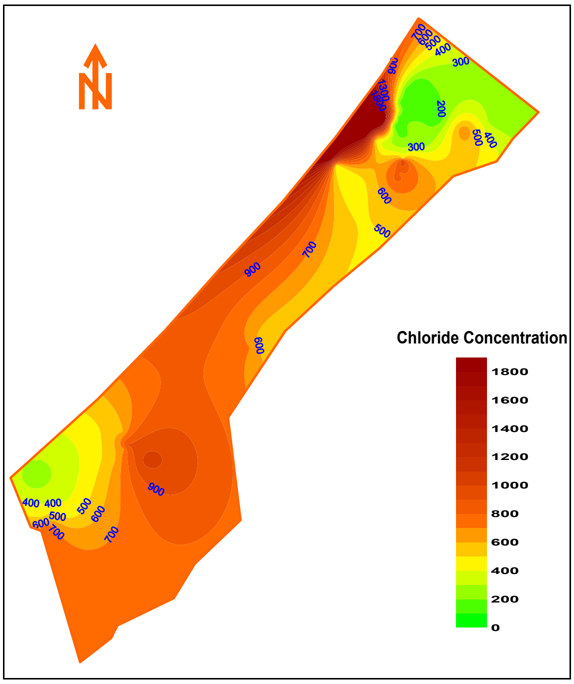


Figure (6.22): Simulated chloride concentration of pumped Groundwater in Gaza Strip (October, 2007)

6.4.4 Utilizing ANN Model for Future Scenarios Predictions

The ANN model was utilized to predict chloride concentration in some domestic wells in Gaza Strip by considering three future scenarios. These future scenarios considered mainly the influence of abstraction and abstraction average rate on chloride concentration of groundwater in Gaza Strip.

6.4.4.1 Scenario 1: No Change of Abstraction Condition

This scenario included that abstraction quantity and abstraction rates will continue as in 2007 abstraction conditions. The ANN model was utilized to predict chloride concentration in the groundwater domestic wells for years 2010, 2020 and

2030. Figures (6.23), (6.24) and (6.25) presented the predicted chloride concentration of pumped groundwater in Gaza Strip for Scenario 1 in 2010, 2020 and 2030. The figures show that chloride concentration increases very rapidly in most areas of Gaza Strip and chloride concentration will exceed the 500 mg/l in most areas of Gaza Strip in 2030.

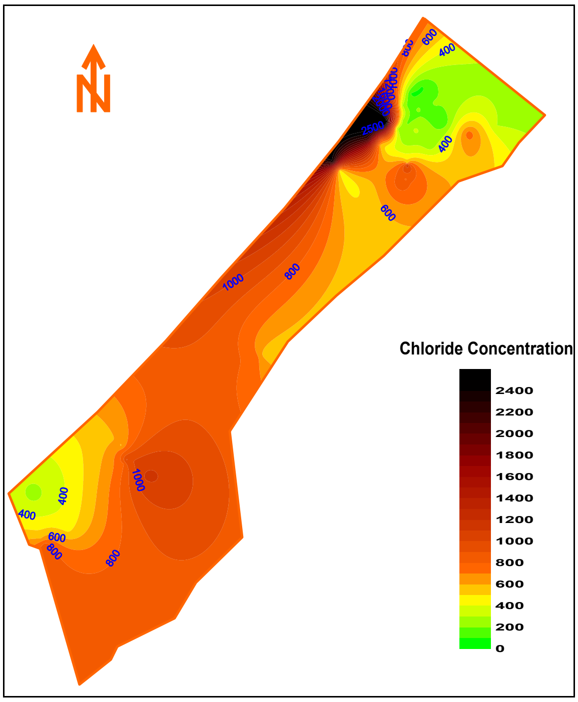


Figure (6.23): Predicted chloride concentration of pumped groundwater in Gaza Strip in 2010 for Scenario 1

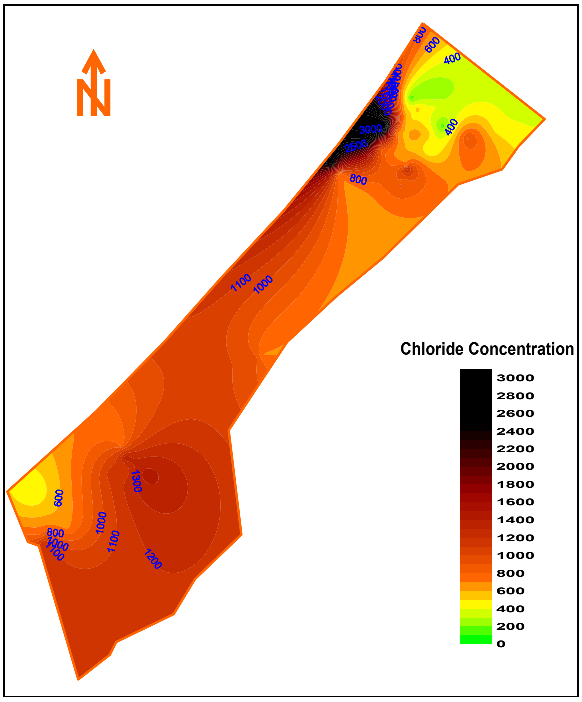


Figure (6.24): Predicted chloride concentration of pumped groundwater in Gaza Strip in 2020 for Scenario 1

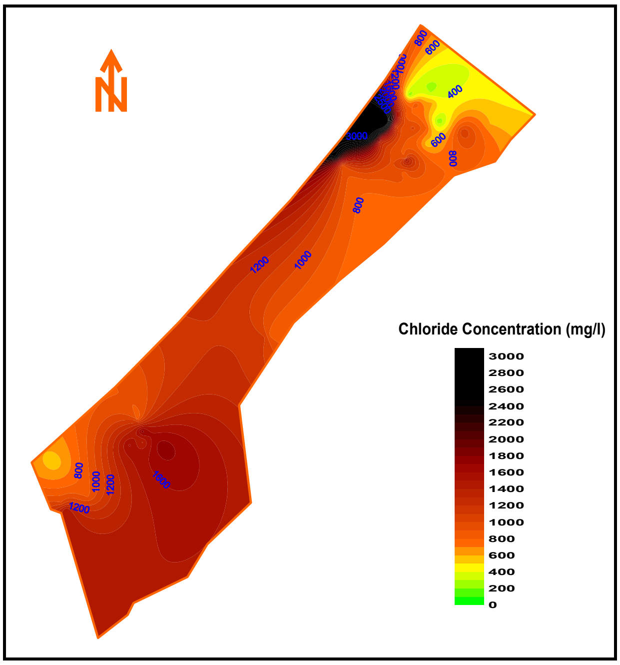


Figure (6.25): Predicted chloride concentration of pumped groundwater in Gaza Strip in 2030 for Scenario 1

6.4.4.2 Scenario 2: The Total Abstraction Will be Reduced by Half

Scenario 2 considered that abstraction quantity and abstraction rates fixed in half value of abstraction in year 2007. The ANN model was utilized to predict chloride concentration on study wells in Gaza Strip for this scenario for years 2010 and 2020. Figures (6.26) and (6.27) presented predicted chloride concentration of pumped groundwater in Gaza Strip for Scenario 2 in 2010 and 2020. The figures showed that chloride concentration decreases slowly in most areas of Gaza Strip except of Khanyounis area, the chloride concentration stays stable and does not improve as other areas because of the aquifer thickness in this area is small relatively to other areas in Gaza Strip. Also it was noted that areas with low chloride concentration increases in slowly rates.

It was noted that predicted chloride concentration of pumped groundwater in Gaza Strip in 2010 for Scenario 2 is almost similar to chloride concentration of pumped groundwater in Gaza Strip in 2001 In addition it was noted that predicted chloride concentration of pumped groundwater in Gaza Strip in 2020 for Scenario 2 is almost similar to chloride concentration of pumped groundwater in Gaza Strip in 1997.

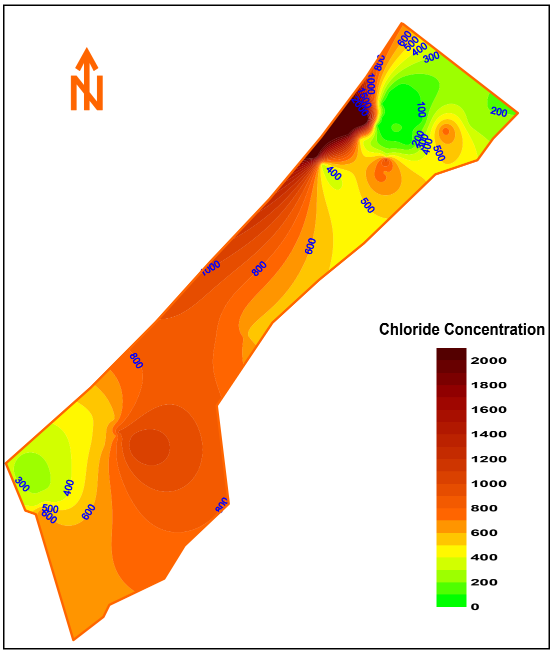


Figure (6.26): Predicted chloride concentration of pumped groundwater in Gaza Strip in 2010 for Scenario 2

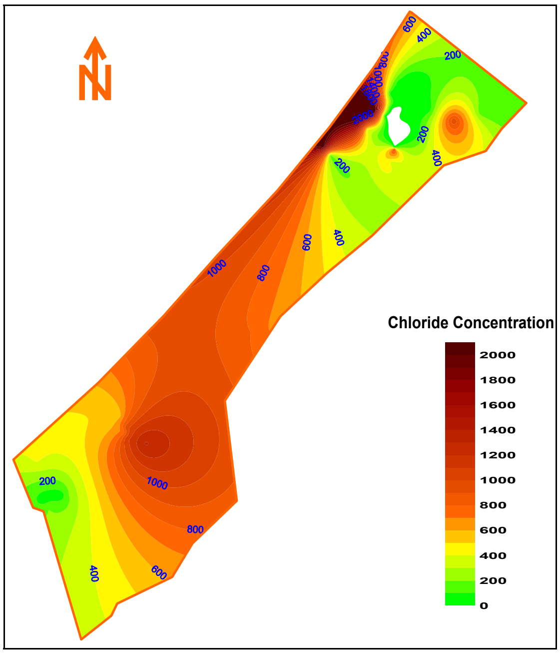


Figure (6.27): Predicted chloride concentration of pumped groundwater in Gaza Strip in 2020 for Scenario 2

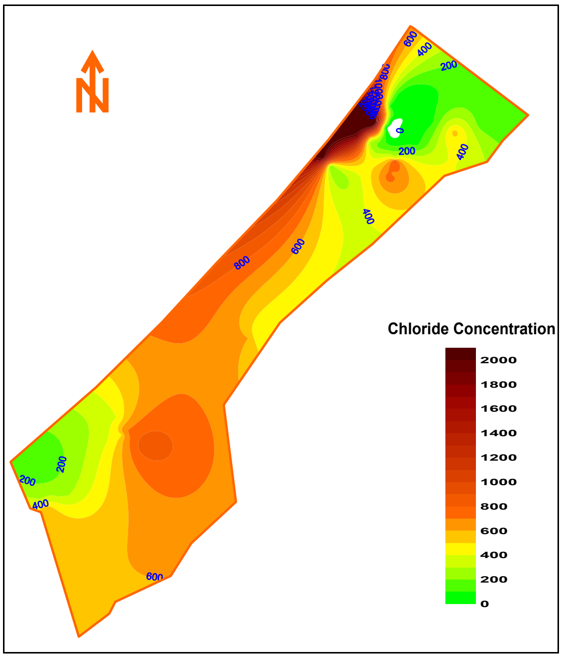
6.4.4.2 Scenario 3: No Abstraction Condition

This scenario considered that no abstraction from groundwater and therefore abstraction quantity and abstraction rates fixed as zero. The ANN model was utilized to predict the reduction of chloride concentration in groundwater for one year of no abstraction. Figure (6.28) presented the reduction of chloride concentration in groundwater for one year of no abstraction

The ANN model was utilized to predict chloride concentration for this scenario for years 2010 and 2020. Figures (6.29) and (6.30) presented the predicted chloride concentration in 2010 and 2020. It was noted that predicted chloride concentration of pumped groundwater in Gaza Strip in 2010 for Scenario 3 is almost similar to chloride concentration of pumped groundwater in Gaza Strip in 1997 In addition it was noted that predicted chloride concentration of pumped groundwater in Gaza Strip in 2020 for Scenario 3 is will reduced to very good levels and there is no salinity problem in most areas of Gaza Strip.

It was noted that the improvement rate of chloride concentration with no abstraction scenario is faster than the case with half abstraction scenario since that the required time for reclamation processes of groundwater with Scenario 3 is less than required time with Scenario 2.

The chloride concentration data of study wells for three Scenarios are represented in Annex 8.



Figures (6.28): The reduction of chloride concentration in groundwater for one year of no abstraction Scenario 3

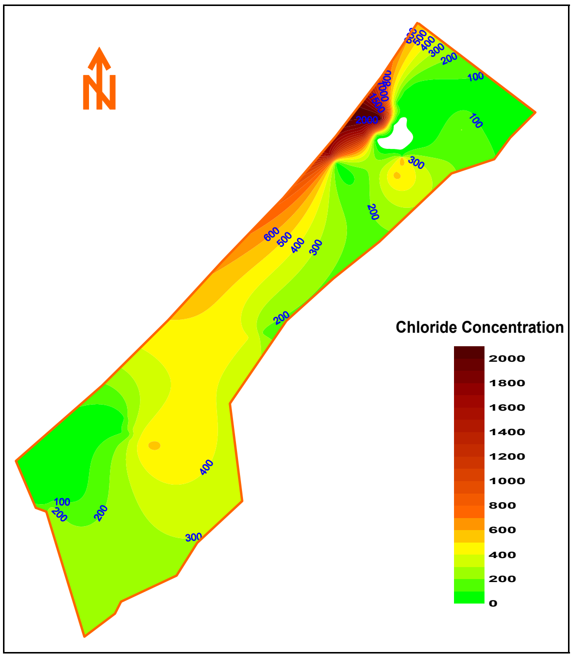


Figure (6.29): Predicted chloride concentration of pumped groundwater in Gaza Strip in 2010 for Scenario 3

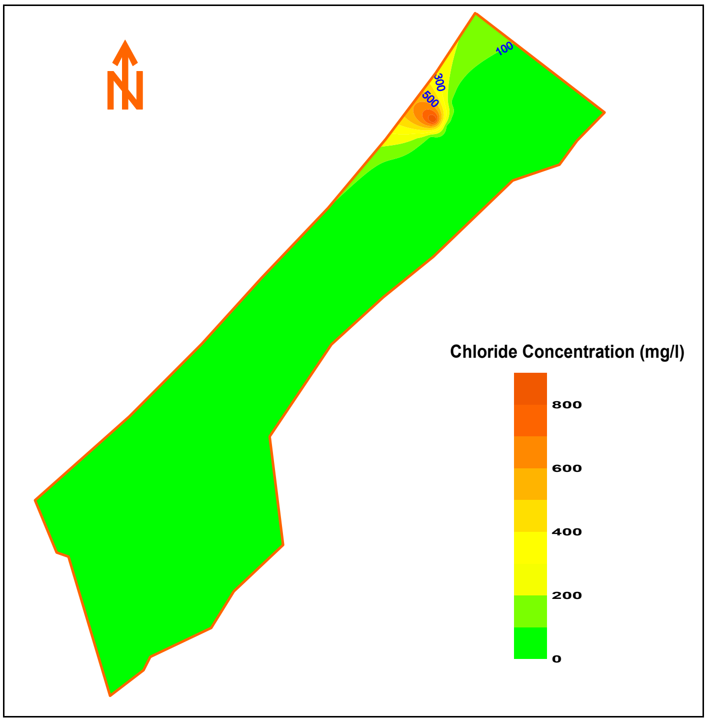


Figure (6.30): Predicted chloride concentration of pumped groundwater in Gaza Strip in 2020 for Scenario 3

6.4.5 Utilizing ANN Model as Decision Making Support Tool

From previous section it was realized that the reduction of abstraction rate reduce the chloride concentration in the domestic wells. Therefore, ANN model was utilized to determine the appropriate abstraction rate which help in stabilize the chloride concentration in the domestic wells and on the other hand, the salinity in the aquifer can be reduced with time. Furthermore, the developed ANN model is used to determine the required duration for each value of abstraction to reclaim groundwater aquifer around well area reach';ing to WHO drinking water standards (250 mg/l).

Detailed study about well R75 in Gaza Governorate is presented as example for applying the ANN model as a decision making support tool. The chloride concentration of well R75 is 889.2 mg/l at October, 2007. Aquifer thickness is 100 meter, life time is 16 year, the recharge average rate of well area is 0.8 mm/m2/month on time phase A and 24.27 mm/m^2/month on time phase B. Moreover, the abstraction average rate of well area is 36.22 mm/m^2/month on time phase A and 31.54 mm/m^2/month on time phase B.

Figure (6.31) presented the annual change of chloride concentration in well R75 according to the changing of abstraction from this well. ANN model result showed that the chloride concentration of well can be kept as present condition, with abstraction 55 m^3/h. It also was found that in case of stopping abstraction from this well, chloride concentration will decrease 27 mg/l per year. This means that local reclamation processes of groundwater aquifer around the well area will take 24 years to reduce chloride concentration to 250 mg/l.

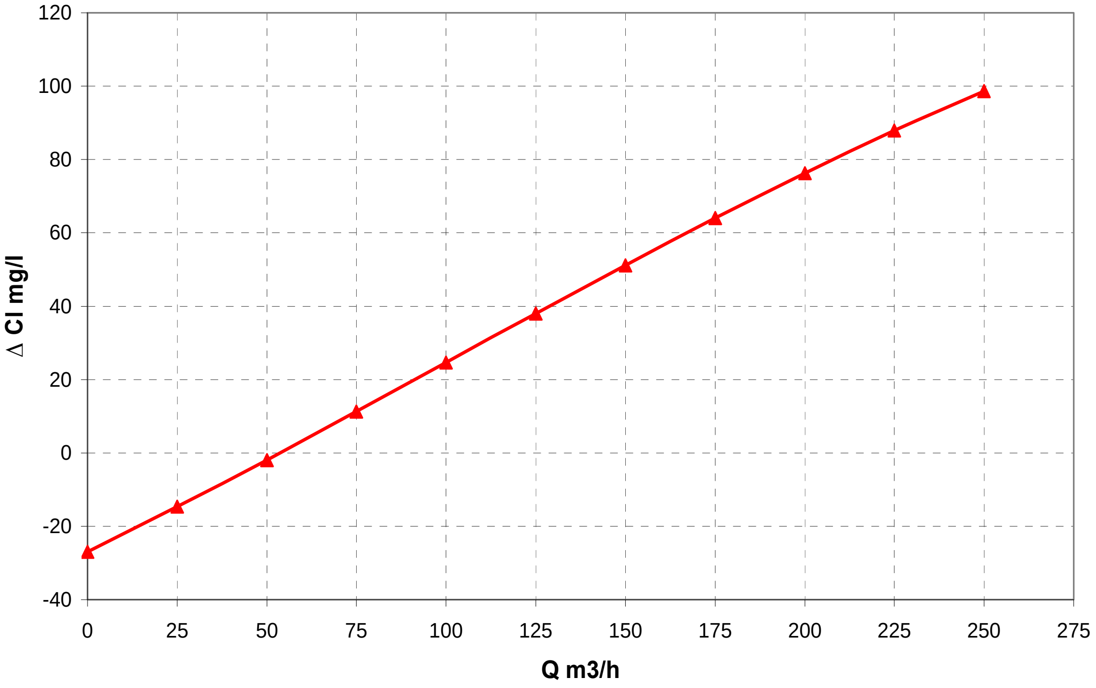


Figure (6.31): Annual change on chloride concentration in well R75 according to changing abstraction in the same well

Chapter (7)

Conclusions and Recommendations

7.1 Conclusions

The following conclusions were made based on the results obtained from the current study:

1. A new approach for Groundwater salinity modelling in Gaza Strip utilizing ANN was successfully developed and applied. ANN model was developed to study the relation between groundwater salinity (represented by chloride concentration in groundwater) and some related hydrological factors such as recharge rate (R), abstraction (Q), abstraction average rate (Qr), life time (Lt), groundwater level (Wl), aquifer thickness (Th), depth from surface to well screen (Dw), and distance from sea shore line (Ds).
2. After a number of modelling trials, the best neural network was Multilayer Perceptron network (MLP) with four layers: an input layer of 6 neurons, first hidden layer with 10 neurons, second hidden layer with 7 neurons and the output layer with 1 neuron . The six input neurons represented the input variables which are: initial chloride concentration (Cl_o), recharge rate (R), abstraction (Q), abstraction average rate (Qr), life time (Lt) and aquifer thickness (Th). The output neuron gives the final chloride concentration (Cl_f).
3. The new approach generated very good results depending high correlation between the observed and predicted values of chloride concentration. The correlation coefficient (r) between the predicted and the observed output values of the ANN model was 0.9848. The high value of correlation coefficient (r) showed that the simulated chloride concentration values using the ANN model were in very good agreement with the observed chloride concentration which mean that ANN model are useful and applicable.
4. The ANN model proved that chloride concentration in groundwater is directly affected by abstraction (Q), abstraction average rate (Qr) and life time (Lt). Furthermore, it was adversely affected by recharge rate (R) and aquifer thickness (Th).
5. The ANN model was successfully utilized in many practical and theoretical applications. It was utilized as analytical tool to study influence of the input variables on chloride concentration. Furthermore, it was utilized as simulation and prediction tool of chloride concentration in domestic wells in Gaza Strip. Other important application of ANN model that it was utilized as decision making support tool.
6. The developed ANN model showed that if the abstraction rate kept the same as in 2007, chloride concentration will increase very rabidly in most areas of Gaza Strip and the availability of fresh water will decrease in disquieting rates by year 2030.

7. The developed ANN model showed that if the abstraction rate is decreased with 50% of 2007 abstraction, the chloride concentration of groundwater will decrease slowly in most areas of Gaza Strip and it will be in 2010 almost similar to chloride concentration of groundwater in Gaza Strip in 2001 and chloride concentration in 2020 is almost similar to chloride concentration of groundwater in Gaza Strip in 1997.
8. The developed ANN model showed that if the abstraction was totally stopped from the aquifer, the chloride concentration of groundwater will decrease rapidly in all areas of Gaza Strip and within one year, chloride concentration will be almost similar to chloride concentration of groundwater in Gaza Strip in 2001 and within three years, chloride concentration will be almost similar to chloride concentration of groundwater in Gaza Strip in 1997.
9. Therefore, the current research showed that ANN model can be used in groundwater quality management and it is comparable to other used approaches such as groundwater modelling and statistical modelling. It showed that the strong remedial actions for solving the groundwater deterioration problem in the aquifer of Gaza Strip (salinity) are reducing the abstraction rate and increasing the recharge quantities to the aquifer.

7.2 Recommendations

The following recommendations were made based on the results obtained from the study:

1. New water sources should be found and the abstraction from Gaza Strip aquifer should be reduced with 50% at least, to solve groundwater salinity problem. This action can reduce the salinity gradually with time and chloride concentration in 2020 will be as in 1997. This result could be achieved only in three years in case of abstraction will totally stopped.
2. New wells should be constructed in appropriate areas that have large aquifer thickness and high ability to infiltrate rainfall to groundwater depending on their adversel reletion with chloride concentration.
3. It is recommended to close old constructed wells to reclaim groundwater aquifer around the well area. In addition, some wells with very high chloride concentration especially at the west area in Gaza city should be closed.
4. Although, the ANN model performed well, further studies about hydrological processes using ANN in Gaza strip will enhance the utilizing ANN as modelling and management approach.
5. Although, the ANN model performed well, further studies about using ANN model in groundwater management approach is recommended. An example of these studies is the effect of increasing recharge areas such as sormwater and treated wastewater infiltration basins, on salinity. In contrast, the extention of urbanized areas and their influence on slainity can be also a future study.

6. It is recommended – in case of data available - a new ANN model to be developed in order to study the influence of other hydrological factors on groundwater salinity such as hydraulic conductivity of the aquifer.
7. Due to the fact that seawater intrusion modelling using hydrogeological approach is data and time consuming, it is recommended to analyse the phenomena using ANN if there is enough related data in future.

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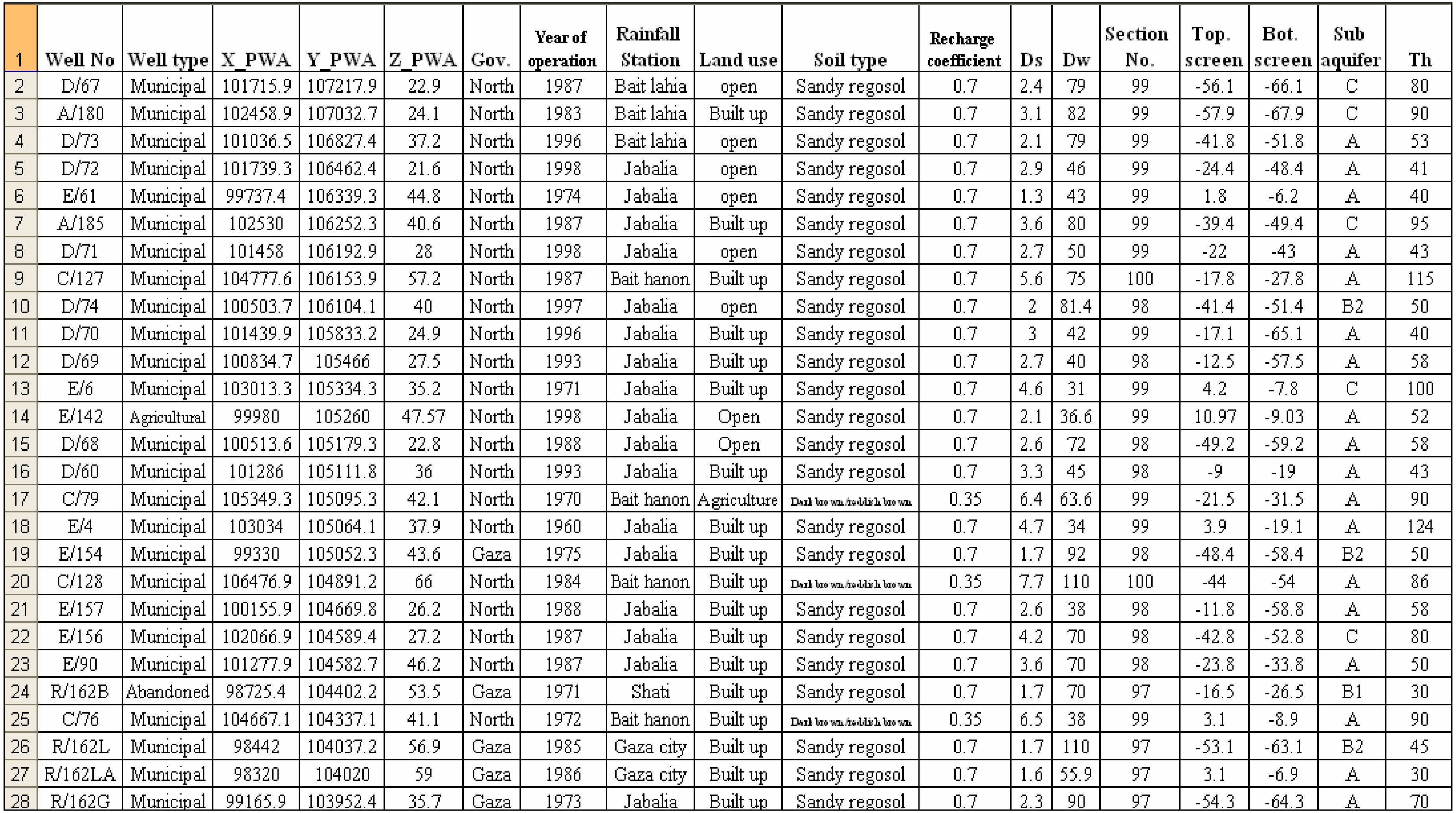
ANNEXES

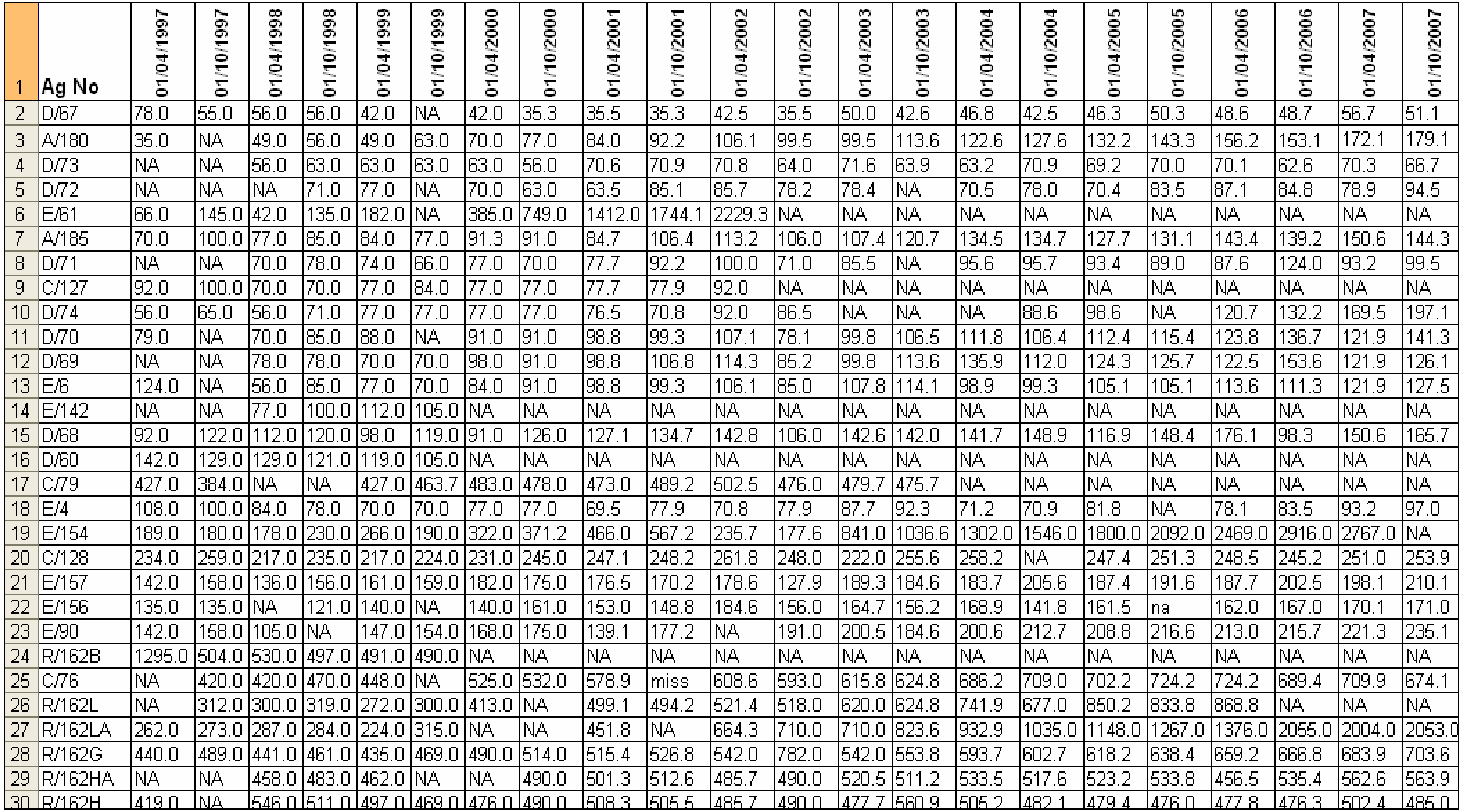
ANNEX 1 : The general information of all study wells



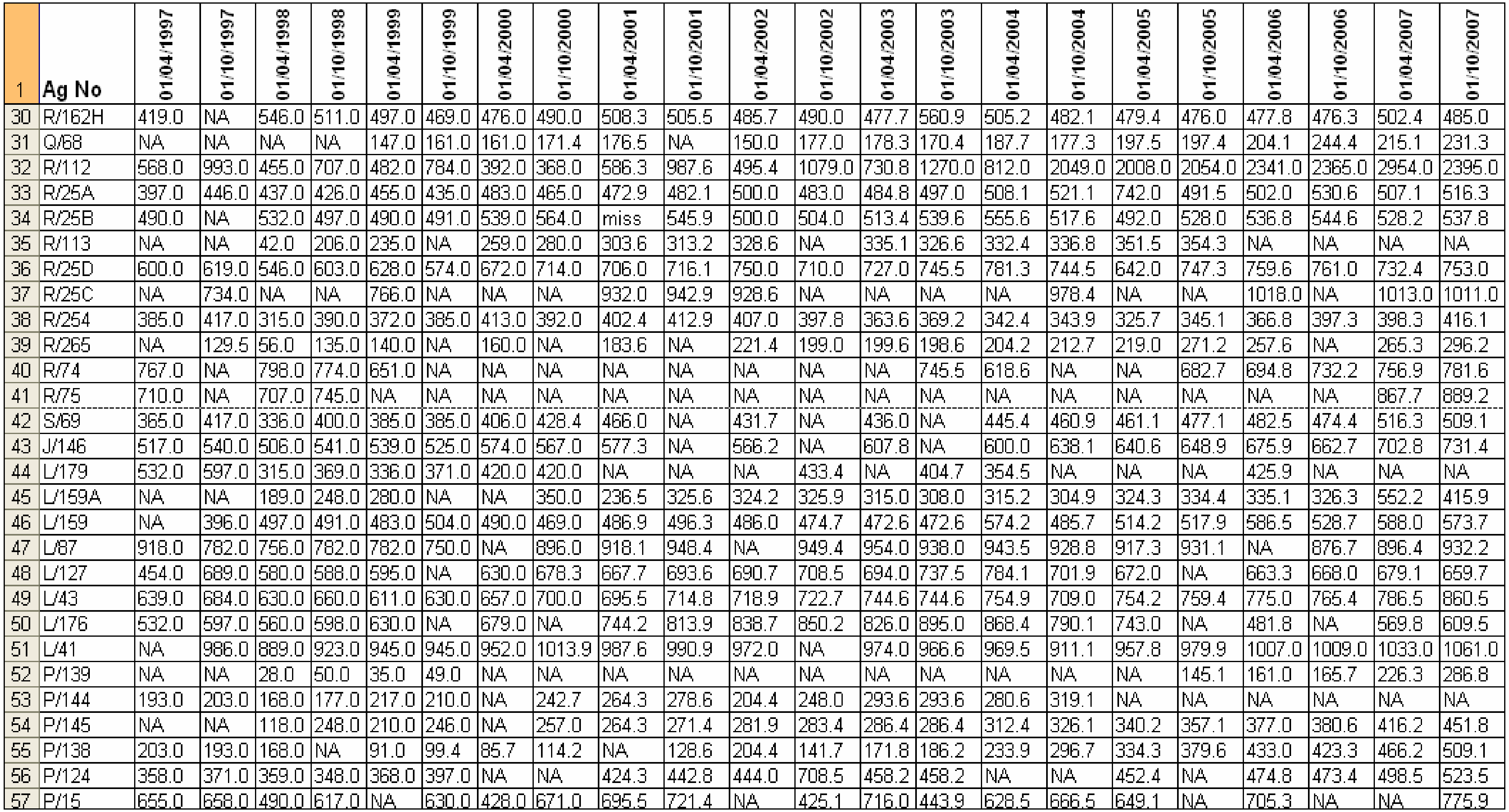
1	Well No	Well type	X_PWA	Y_PWA	Z_PWA	Gov.	Year of operation	Rainfall Station	Land use	Soil type	Recharge coefficient	Ds	Dw	Section No.	Top. screen	Bot. screen	Sub aquifer	Th
2	D/67	Municipal	101715.9	107217.9	22.9	North	1987	Bait lahia	open	Sandy regosol	0.7	2.4	79	99	-56.1	-66.1	C	80
3	A/180	Municipal	102458.9	107032.7	24.1	North	1983	Bait lahia	Built up	Sandy regosol	0.7	3.1	82	99	-57.9	-67.9	C	90
4	D/73	Municipal	101036.5	106827.4	37.2	North	1996	Bait lahia	open	Sandy regosol	0.7	2.1	79	99	-41.8	-51.8	A	53
5	D/72	Municipal	101739.3	106462.4	21.6	North	1998	Jabalia	open	Sandy regosol	0.7	2.9	46	99	-24.4	-48.4	A	41
6	E/61	Municipal	99737.4	106339.3	44.8	North	1974	Jabalia	open	Sandy regosol	0.7	1.3	43	99	1.8	-6.2	A	40
7	A/185	Municipal	102530	106252.3	40.6	North	1987	Jabalia	Built up	Sandy regosol	0.7	3.6	80	99	-39.4	-49.4	C	95
8	D/71	Municipal	101458	106192.9	28	North	1998	Jabalia	open	Sandy regosol	0.7	2.7	50	99	-22	-43	A	43
9	C/127	Municipal	104777.6	106153.9	57.2	North	1987	Bait hanon	Built up	Sandy regosol	0.7	5.6	75	100	-17.8	-27.8	A	115
10	D/74	Municipal	100503.7	106104.1	40	North	1997	Jabalia	open	Sandy regosol	0.7	2	81.4	98	-41.4	-51.4	B2	50
11	D/70	Municipal	101439.9	105833.2	24.9	North	1996	Jabalia	Built up	Sandy regosol	0.7	3	42	99	-17.1	-65.1	A	40
12	D/69	Municipal	100834.7	105466	27.5	North	1993	Jabalia	Built up	Sandy regosol	0.7	2.7	40	98	-12.5	-57.5	A	58
13	E/6	Municipal	103013.3	105334.3	35.2	North	1971	Jabalia	Built up	Sandy regosol	0.7	4.6	31	99	4.2	-7.8	C	100
14	E/142	Agricultural	99980	105260	47.57	North	1998	Jabalia	Open	Sandy regosol	0.7	2.1	36.6	99	10.97	-9.03	A	52
15	D/68	Municipal	100513.6	105179.3	22.8	North	1988	Jabalia	Open	Sandy regosol	0.7	2.6	72	98	-49.2	-59.2	A	58
16	D/60	Municipal	101286	105111.8	36	North	1993	Jabalia	Built up	Sandy regosol	0.7	3.3	45	98	-9	-19	A	43
17	C/79	Municipal	105349.3	105095.3	42.1	North	1970	Bait hanon	Agriculture	Dark brown/reddish brown	0.35	6.4	63.6	99	-21.5	-31.5	A	90
18	E/4	Municipal	103034	105064.1	37.9	North	1960	Jabalia	Built up	Sandy regosol	0.7	4.7	34	99	3.9	-19.1	A	124
19	E/154	Municipal	99330	105052.3	43.6	Gaza	1975	Jabalia	Built up	Sandy regosol	0.7	1.7	92	98	-48.4	-58.4	B2	50
20	C/128	Municipal	106476.9	104891.2	66	North	1984	Bait hanon	Built up	Dark brown/reddish brown	0.35	7.7	110	100	-44	-54	A	86
21	E/157	Municipal	100155.9	104669.8	26.2	North	1988	Jabalia	Built up	Sandy regosol	0.7	2.6	38	98	-11.8	-58.8	A	58
22	E/156	Municipal	102066.9	104589.4	27.2	North	1987	Jabalia	Built up	Sandy regosol	0.7	4.2	70	98	-42.8	-52.8	C	80
23	E/90	Municipal	101277.9	104582.7	46.2	North	1987	Jabalia	Built up	Sandy regosol	0.7	3.6	70	98	-23.8	-33.8	A	50
24	R/162B	Abandoned	98725.4	104402.2	53.5	Gaza	1971	Shati	Built up	Sandy regosol	0.7	1.7	70	97	-16.5	-26.5	B1	30
25	C/76	Municipal	104667.1	104337.1	41.1	North	1972	Bait hanon	Built up	Dark brown/reddish brown	0.35	6.5	38	99	3.1	-8.9	A	90
26	R/162L	Municipal	98442	104037.2	56.9	Gaza	1985	Gaza city	Built up	Sandy regosol	0.7	1.7	110	97	-53.1	-63.1	B2	45
27	R/162LA	Municipal	98320	104020	59	Gaza	1986	Gaza city	Built up	Sandy regosol	0.7	1.6	55.9	97	3.1	-6.9	A	30
28	R/162G	Municipal	99165.9	103952.4	35.7	Gaza	1973	Jabalia	Built up	Sandy regosol	0.7	2.3	90	97	-54.3	-64.3	A	70

1	Well No	Well type	X_PWA	Y_PWA	Z_PWA	Gov.	Year of operation	Rainfall Station	Land use	Soil type	Recharge coefficient	Ds	Dw	Section No.	Top. screen	Bot. screen	Sub aquifer	Th
28	R/162G	Municipal	99165.9	103952.4	35.7	Gaza	1973	Jabalia	Built up	Sandy regosol	0.7	2.3	90	97	-54.3	-64.3	A	70
29	R/162HA	Municipal	99030	103700	32	Gaza	1990	Gaza city	Built up	Sandy regosol	0.7	2.4	85	97	-53	-63	A	69
30	R/162H	Municipal	99054.7	103668	33	Gaza	1987	Gaza city	Built up	Sandy regosol	0.7	2.4	90	97	-57	-67	A	69
31	Q/68	Municipal	102220.5	103530	42.3	North	1999	Tuffah	open	Dark brown/reddish brown	0.7	5	73	98	-30.7	-54.7	A	104
32	R/112	Municipal	96061.2	102650.2	20.7	Gaza	1965	Gaza city	Built up	Sandy regosol	0.7	0.6	36	96	-15.3	-24.3	A	30
33	R/25A	Municipal	100758.5	102581.4	32.3	Gaza	1950	Tuffah	Agriculture	Dark brown/reddish brown	0.7	4.4	85	97	-52.7	-62.7	A	109
34	R/25B	Municipal	100778.7	102527.2	33.1	Gaza	1950	Tuffah	Agriculture	Dark brown/reddish brown	0.7	4.5	52	97	-18.9	-28.9	A	109
35	R/113	Agricultural	96180	102500	27	Gaza	1965	Gaza city	Built up	Sandy regosol	0.7	0.8	32	96	-5	-15	A+B	40
36	R/25D	Municipal	100819.9	102495.9	34.5	Gaza	1972	Tuffah	Agriculture	Dark brown/reddish brown	0.7	4.5	50	97	-15.5	-25.5	A	109
37	R/25C	Municipal	100774.7	102456	34.4	Gaza	1957	Tuffah	Agriculture	Dark brown/reddish brown	0.7	4.5	45	97	-10.6	-20.6	A	109
38	R/254	Municipal	96542.4	102055.5	36.1	Gaza	1984	Gaza city	Built up	Sandy regosol	0.7	1.4	46	96	-9.9	-35.9	A	36
39	R/265	Municipal	95809.4	101707.6	39.1	Gaza	1995	Gaza city	open	Sandy regosol	0.7	1	39	95	0.1	-26.9	B1	40
40	R/74	Municipal	100661.2	101542.9	44.7	Gaza	1993	Tuffah	Built up	Loess soil	0.35	5	45	97	-0.3	-10.3	A	100
41	R/75	Municipal	100417.2	101298.9	42.1	Gaza	1988	Tuffah	Built up	Loess soil	0.35	5	62	97	-19.9	-29.9	A	100
42	S/69	Municipal	91767.7	90702.9	67.7	Midel	1989	Bair El balah	Agriculture	Loessial sandy soil	0.25	5.1	72.7	90	-5	-15	A	71
43	J/146	Municipal	91200.3	90460.4	60.9	Midel	1987	Bair El balah	Agriculture	Loessial sandy soil	0.25	4.8	62	90	-1.1	-11.1	A	78
44	L/179	Municipal	85572	87460.6	28.5	Khan.	1987	Khan Younis	Open	Loessial sandy soil	0.35	3	86	87	-57.5	-67.5	C	35
45	L/159A	Municipal	82678	85081.9	45.1	Khan.	1998	Khan Younis	Open	Loessial sandy soil	0.7	2.5	62	85	-16.9	-26.9	B2	30
46	L/159	Municipal	82604.9	85047	42.8	Khan.	1974	Khan Younis	Open	Loessial sandy soil	0.7	2.4	42	85	0.8	-42.7	B1+B2	40
47	L/87	Municipal	83040.2	84200.7	52.7	Khan.	1970	Khan Younis	Built up	Loessial sandy soil	0.35	3.4	82	85	-29.3	-39.3	C	45
48	L/127	Municipal	82850.9	83935.1	53	Khan.	1987	Khan Younis	Built up	Loessial sandy soil	0.35	3.4	60	85	-7	-17	A	30
49	L/43	Municipal	83062.9	83461.4	59.9	Khan.	1971	Khan Younis	Built up	Loessial sandy soil	0.35	3.9	79	85	-19.1	-29.1	A	69
50	L/176	Municipal	82186.6	83276.7	38.4	Khan.	1988	Khan Younis	open	Loessial sandy soil	0.35	3.4	110	84	-71.6	-81.6	C	50
51	L/41	Municipal	84345.8	83160.5	61.6	Khan.	1971	Khan Younis	Built up	Loessial sandy soil	0.25	5.1	54	85	7.6	-43.4	A	60
52	P/139	Municipal	77166.6	82010.5	9.8	Khan.	1998	Rafah	open	Sandy regosol	0.7	0.8	30	82	-20.2	-30.2	C	30
53	P/144	Municipal	78301.9	80376.3	32.2	Rafeh	1993	Rafah	open	Sandy regosol	0.7	2.8	80	82	-47.8	-57.8	C	30
54	P/145	Municipal	79368.6	79856.4	48.2	Rafeh	1996	Rafah	open	Loessial sandy soil	0.7	4	75	82	-26.8	-32.8	C	40
55	P/138	Municipal	78772.7	79764.8	47.7	Rafeh	1995	Rafah	open	Loessial sandy soil	0.7	3.6	67	82	-19.3	-37.3	B1	33
56	P/124	Municipal	77598	79414	24.2	Rafeh	1987	Rafah	Built up	Sandy regosol	0.7	3.1	48	81	-23.8	-33.8	A	42
57	P/15	Municipal	77926.8	78904.2	22	Rafeh	1987	Rafah	Built up	Loessial sandy soil	0.35	3.6	18	81	4	-16	A	34

ANNEX 2 : Chloride concentration (mg/l) of all study wells from 1997 to 2006

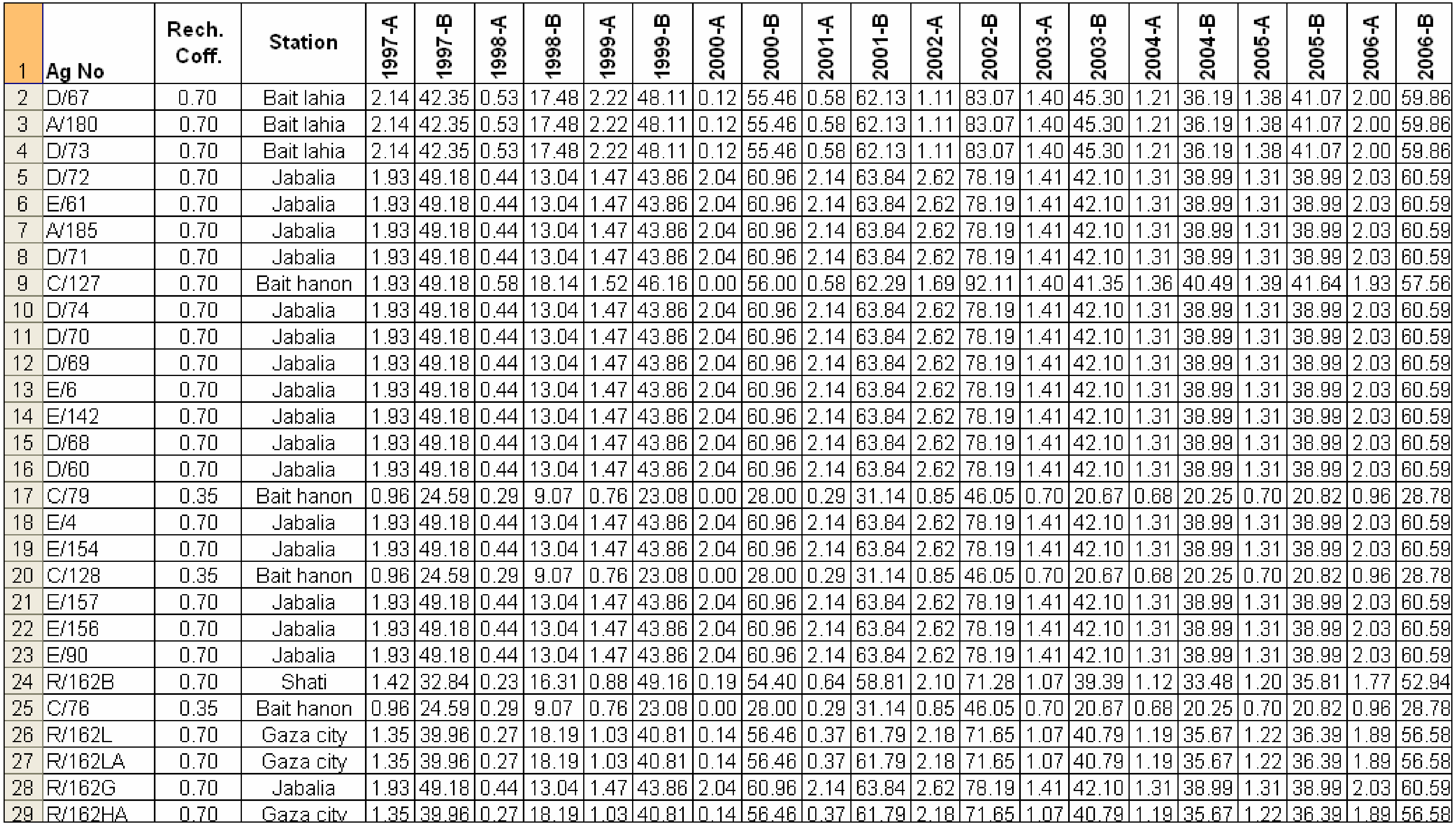


1	Ag No	01/04/1997	01/10/1997	01/04/1998	01/10/1998	01/04/1999	01/10/1999	01/04/2000	01/10/2000	01/04/2001	01/10/2001	01/04/2002	01/10/2002	01/04/2003	01/10/2003	01/04/2004	01/10/2004	01/04/2005	01/10/2005	01/04/2006	01/10/2006	01/04/2007	01/10/2007
2	D/67	78.0	55.0	56.0	56.0	42.0	NA	42.0	35.3	35.5	35.3	42.5	35.5	50.0	42.6	46.8	42.5	46.3	50.3	48.6	48.7	56.7	51.1
3	A/180	35.0	NA	49.0	56.0	49.0	63.0	70.0	77.0	84.0	92.2	106.1	99.5	99.5	113.6	122.6	127.6	132.2	143.3	156.2	153.1	172.1	179.1
4	D/73	NA	NA	56.0	63.0	63.0	63.0	63.0	56.0	70.6	70.9	70.8	64.0	71.6	63.9	63.2	70.9	69.2	70.0	70.1	62.6	70.3	66.7
5	D/72	NA	NA	NA	71.0	77.0	NA	70.0	63.0	63.5	85.1	85.7	78.2	78.4	NA	70.5	78.0	70.4	83.5	87.1	84.8	78.9	94.5
6	E/61	66.0	145.0	42.0	135.0	182.0	NA	385.0	749.0	1412.0	1744.1	2229.3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
7	A/185	70.0	100.0	77.0	85.0	84.0	77.0	91.3	91.0	84.7	106.4	113.2	106.0	107.4	120.7	134.5	134.7	127.7	131.1	143.4	139.2	150.6	144.3
8	D/71	NA	NA	70.0	78.0	74.0	66.0	77.0	70.0	77.7	92.2	100.0	71.0	85.5	NA	95.6	95.7	93.4	89.0	87.6	124.0	93.2	99.5
9	C/127	92.0	100.0	70.0	70.0	77.0	84.0	77.0	77.0	77.7	77.9	92.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
10	D/74	56.0	65.0	56.0	71.0	77.0	77.0	77.0	77.0	76.5	70.8	92.0	86.5	NA	NA	NA	88.6	98.6	NA	120.7	132.2	169.5	197.1
11	D/70	79.0	NA	70.0	85.0	88.0	NA	91.0	91.0	98.8	99.3	107.1	78.1	99.8	106.5	111.8	106.4	112.4	115.4	123.8	136.7	121.9	141.3
12	D/69	NA	NA	78.0	78.0	70.0	70.0	98.0	91.0	98.8	106.8	114.3	85.2	99.8	113.6	135.9	112.0	124.3	125.7	122.5	153.6	121.9	126.1
13	E/6	124.0	NA	56.0	85.0	77.0	70.0	84.0	91.0	98.8	99.3	106.1	85.0	107.8	114.1	98.9	99.3	105.1	105.1	113.6	111.3	121.9	127.5
14	E/142	NA	NA	77.0	100.0	112.0	105.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
15	D/68	92.0	122.0	112.0	120.0	98.0	119.0	91.0	126.0	127.1	134.7	142.8	106.0	142.6	142.0	141.7	148.9	116.9	148.4	176.1	98.3	150.6	165.7
16	D/60	142.0	129.0	129.0	121.0	119.0	105.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
17	C/79	427.0	384.0	NA	NA	427.0	463.7	483.0	478.0	473.0	489.2	502.5	476.0	479.7	475.7	NA	NA	NA	NA	NA	NA	NA	NA
18	E/4	108.0	100.0	84.0	78.0	70.0	70.0	77.0	77.0	69.5	77.9	70.8	77.9	87.7	92.3	71.2	70.9	81.8	NA	78.1	83.5	93.2	97.0
19	E/154	189.0	180.0	178.0	230.0	266.0	190.0	322.0	371.2	466.0	567.2	235.7	177.6	841.0	1036.6	1302.0	1546.0	1800.0	2092.0	2469.0	2916.0	2767.0	NA
20	C/128	234.0	259.0	217.0	235.0	217.0	224.0	231.0	245.0	247.1	248.2	261.8	248.0	222.0	255.6	258.2	NA	247.4	251.3	248.5	245.2	251.0	253.9
21	E/157	142.0	158.0	136.0	156.0	161.0	159.0	182.0	175.0	176.5	170.2	178.6	127.9	189.3	184.6	183.7	205.6	187.4	191.6	187.7	202.5	198.1	210.1
22	E/156	135.0	135.0	NA	121.0	140.0	NA	140.0	161.0	153.0	148.8	184.6	156.0	164.7	156.2	168.9	141.8	161.5	na	162.0	167.0	170.1	171.0
23	E/90	142.0	158.0	105.0	NA	147.0	154.0	168.0	175.0	139.1	177.2	NA	191.0	200.5	184.6	200.6	212.7	208.8	216.6	213.0	215.7	221.3	235.1
24	R/162B	1295.0	504.0	530.0	497.0	491.0	490.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
25	C/76	NA	420.0	420.0	470.0	448.0	NA	525.0	532.0	578.9	miss	608.6	593.0	615.8	624.8	686.2	709.0	702.2	724.2	724.2	689.4	709.9	674.1
26	R/162L	NA	312.0	300.0	319.0	272.0	300.0	413.0	NA	499.1	494.2	521.4	518.0	620.0	624.8	741.9	677.0	850.2	833.8	868.8	NA	NA	NA
27	R/162LA	262.0	273.0	287.0	284.0	224.0	315.0	NA	NA	451.8	NA	664.3	710.0	710.0	823.6	932.9	1035.0	1148.0	1267.0	1376.0	2055.0	2004.0	2053.0
28	R/162G	440.0	489.0	441.0	461.0	435.0	469.0	490.0	514.0	515.4	526.8	542.0	782.0	542.0	553.8	593.7	602.7	618.2	638.4	659.2	666.8	683.9	703.6
29	R/162HA	NA	NA	458.0	483.0	462.0	NA	NA	490.0	501.3	512.6	485.7	490.0	520.5	511.2	533.5	517.6	523.2	533.8	456.5	535.4	562.6	563.9
30	R/162H	419.0	NA	546.0	511.0	497.0	469.0	476.0	490.0	508.3	505.5	485.7	490.0	477.7	560.9	505.2	482.1	479.4	476.0	477.8	476.3	502.4	485.0



1	Ag No	01/04/1997	01/10/1997	01/04/1998	01/10/1998	01/04/1999	01/10/1999	01/04/2000	01/10/2000	01/04/2001	01/10/2001	01/04/2002	01/10/2002	01/04/2003	01/10/2003	01/04/2004	01/10/2004	01/04/2005	01/10/2005	01/04/2006	01/10/2006	01/04/2007	01/10/2007
30	R/162H	419.0	NA	546.0	511.0	497.0	469.0	476.0	490.0	508.3	505.5	485.7	490.0	477.7	560.9	505.2	482.1	479.4	476.0	477.8	476.3	502.4	485.0
31	Q/68	NA	NA	NA	NA	147.0	161.0	161.0	171.4	176.5	NA	150.0	177.0	178.3	170.4	187.7	177.3	197.5	197.4	204.1	244.4	215.1	231.3
32	R/112	568.0	993.0	455.0	707.0	482.0	784.0	392.0	368.0	586.3	987.6	495.4	1079.0	730.8	1270.0	812.0	2049.0	2008.0	2054.0	2341.0	2365.0	2954.0	2395.0
33	R/25A	397.0	446.0	437.0	426.0	455.0	435.0	483.0	465.0	472.9	482.1	500.0	483.0	484.8	497.0	508.1	521.1	742.0	491.5	502.0	530.6	507.1	516.3
34	R/25B	490.0	NA	532.0	497.0	490.0	491.0	539.0	564.0	miss	545.9	500.0	504.0	513.4	539.6	555.6	517.6	492.0	528.0	536.8	544.6	528.2	537.8
35	R/113	NA	NA	42.0	206.0	235.0	NA	259.0	280.0	303.6	313.2	328.6	NA	335.1	326.6	332.4	336.8	351.5	354.3	NA	NA	NA	NA
36	R/25D	600.0	619.0	546.0	603.0	628.0	574.0	672.0	714.0	706.0	716.1	750.0	710.0	727.0	745.5	781.3	744.5	642.0	747.3	759.6	761.0	732.4	753.0
37	R/25C	NA	734.0	NA	NA	766.0	NA	NA	NA	932.0	942.9	928.6	NA	NA	NA	NA	978.4	NA	NA	1018.0	NA	1013.0	1011.0
38	R/254	385.0	417.0	315.0	390.0	372.0	385.0	413.0	392.0	402.4	412.9	407.0	397.8	363.6	369.2	342.4	343.9	325.7	345.1	366.8	397.3	398.3	416.1
39	R/265	NA	129.5	56.0	135.0	140.0	NA	160.0	NA	183.6	NA	221.4	199.0	199.6	198.6	204.2	212.7	219.0	271.2	257.6	NA	265.3	296.2
40	R/74	767.0	NA	798.0	774.0	651.0	NA	NA	NA	NA	NA	NA	NA	NA	745.5	618.6	NA	NA	682.7	694.8	732.2	756.9	781.6
41	R/75	710.0	NA	707.0	745.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	867.7	889.2
42	S/69	365.0	417.0	336.0	400.0	385.0	385.0	406.0	428.4	466.0	NA	431.7	NA	436.0	NA	445.4	460.9	461.1	477.1	482.5	474.4	516.3	509.1
43	J/146	517.0	540.0	506.0	541.0	539.0	525.0	574.0	567.0	577.3	NA	566.2	NA	607.8	NA	600.0	638.1	640.6	648.9	675.9	662.7	702.8	731.4
44	L/179	532.0	597.0	315.0	369.0	336.0	371.0	420.0	420.0	NA	NA	NA	433.4	NA	404.7	354.5	NA	NA	NA	425.9	NA	NA	NA
45	L/159A	NA	NA	189.0	248.0	280.0	NA	NA	350.0	236.5	325.6	324.2	325.9	315.0	308.0	315.2	304.9	324.3	334.4	335.1	326.3	552.2	415.9
46	L/159	NA	396.0	497.0	491.0	483.0	504.0	490.0	469.0	486.9	496.3	486.0	474.7	472.6	472.6	574.2	485.7	514.2	517.9	586.5	528.7	588.0	573.7
47	L/87	918.0	782.0	756.0	782.0	782.0	750.0	NA	896.0	918.1	948.4	NA	949.4	954.0	938.0	943.5	928.8	917.3	931.1	NA	876.7	896.4	932.2
48	L/127	454.0	689.0	580.0	588.0	595.0	NA	630.0	678.3	667.7	693.6	690.7	708.5	694.0	737.5	784.1	701.9	672.0	NA	663.3	668.0	679.1	659.7
49	L/43	639.0	684.0	630.0	660.0	611.0	630.0	657.0	700.0	695.5	714.8	718.9	722.7	744.6	744.6	754.9	709.0	754.2	759.4	775.0	765.4	786.5	860.5
50	L/176	532.0	597.0	560.0	598.0	630.0	NA	679.0	NA	744.2	813.9	838.7	850.2	826.0	895.0	868.4	790.1	743.0	NA	481.8	NA	569.8	609.5
51	L/41	NA	986.0	889.0	923.0	945.0	945.0	952.0	1013.9	987.6	990.9	972.0	NA	974.0	966.6	969.5	911.1	957.8	979.9	1007.0	1009.0	1033.0	1061.0
52	P/139	NA	NA	28.0	50.0	35.0	49.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	145.1	161.0	165.7	226.3	286.8
53	P/144	193.0	203.0	168.0	177.0	217.0	210.0	NA	242.7	264.3	278.6	204.4	248.0	293.6	293.6	280.6	319.1	NA	NA	NA	NA	NA	NA
54	P/145	NA	NA	118.0	248.0	210.0	246.0	NA	257.0	264.3	271.4	281.9	283.4	286.4	286.4	312.4	326.1	340.2	357.1	377.0	380.6	416.2	451.8
55	P/138	203.0	193.0	168.0	NA	91.0	99.4	85.7	114.2	NA	128.6	204.4	141.7	171.8	186.2	233.9	296.7	334.3	379.6	433.0	423.3	466.2	509.1
56	P/124	358.0	371.0	359.0	348.0	368.0	397.0	NA	NA	424.3	442.8	444.0	708.5	458.2	458.2	NA	NA	452.4	NA	474.8	473.4	498.5	523.5
57	P/15	655.0	658.0	490.0	617.0	NA	630.0	428.0	671.0	695.5	721.4	NA	425.1	716.0	443.9	628.5	666.5	649.1	NA	705.3	NA	NA	775.9

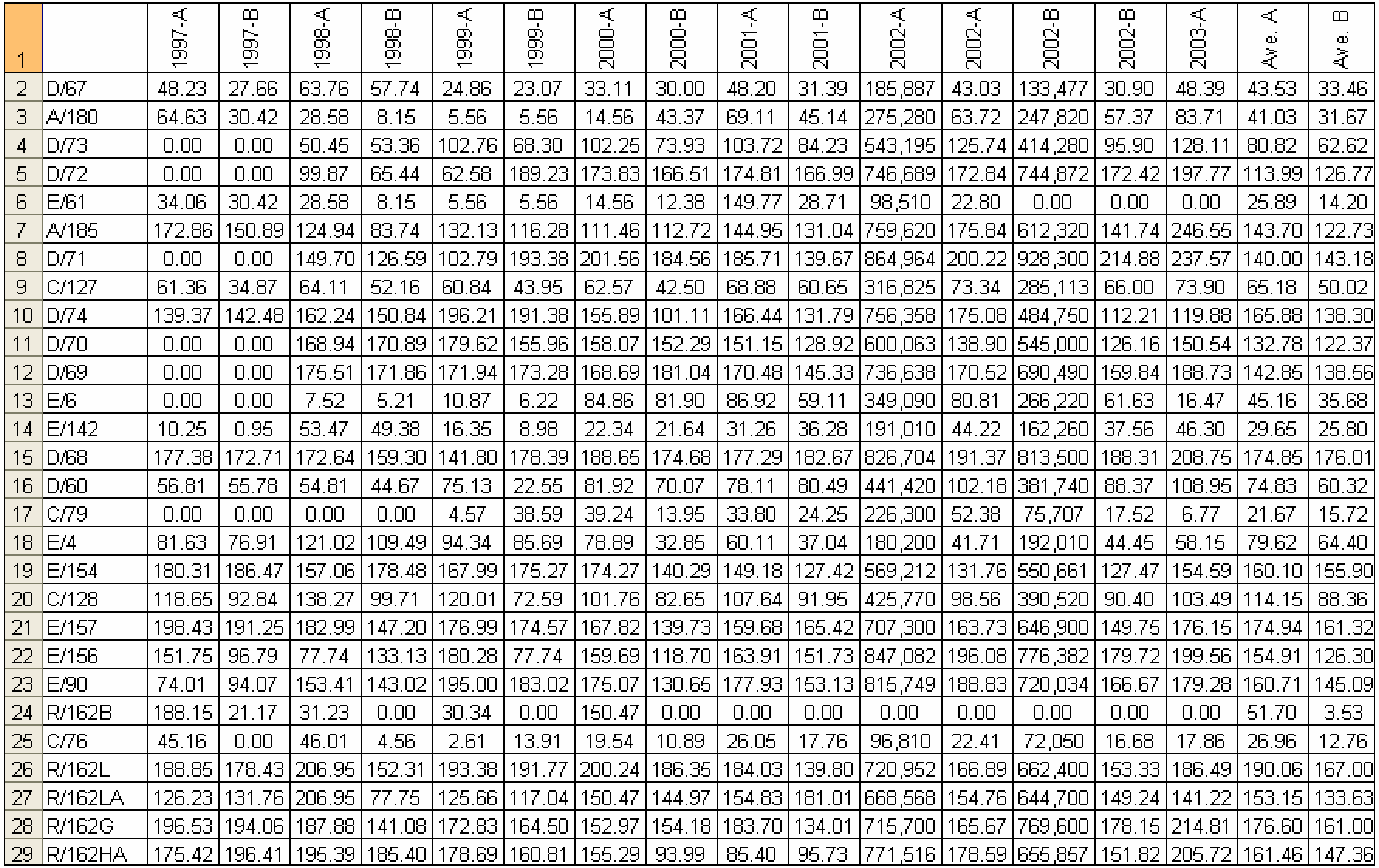
ANNEX 3 : Recharge rate (mm/m^2/month) for all study wells from 1997 to 2006



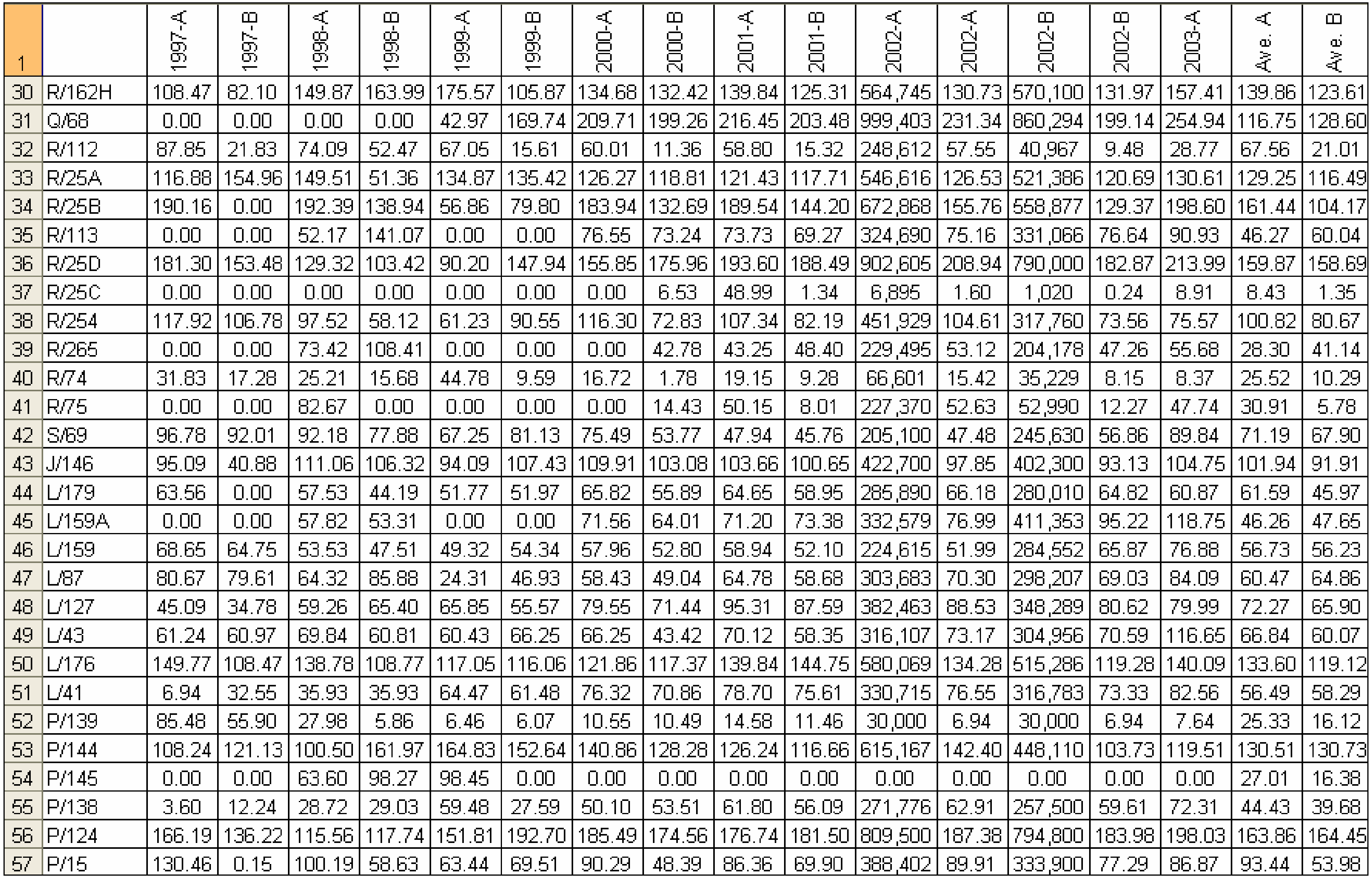
1	Ag No	Rech. Coff.	Station	1997-A	1997-B	1998-A	1998-B	1999-A	1999-B	2000-A	2000-B	2001-A	2001-B	2002-A	2002-B	2003-A	2003-B	2004-A	2004-B	2005-A	2005-B	2006-A	2006-B
2	D/67	0.70	Bait lahia	2.14	42.35	0.53	17.48	2.22	48.11	0.12	55.46	0.58	62.13	1.11	83.07	1.40	45.30	1.21	36.19	1.38	41.07	2.00	59.86
3	A/180	0.70	Bait lahia	2.14	42.35	0.53	17.48	2.22	48.11	0.12	55.46	0.58	62.13	1.11	83.07	1.40	45.30	1.21	36.19	1.38	41.07	2.00	59.86
4	D/73	0.70	Bait lahia	2.14	42.35	0.53	17.48	2.22	48.11	0.12	55.46	0.58	62.13	1.11	83.07	1.40	45.30	1.21	36.19	1.38	41.07	2.00	59.86
5	D/72	0.70	Jabalia	1.93	49.18	0.44	13.04	1.47	43.86	2.04	60.96	2.14	63.84	2.62	78.19	1.41	42.10	1.31	38.99	1.31	38.99	2.03	60.59
6	E/61	0.70	Jabalia	1.93	49.18	0.44	13.04	1.47	43.86	2.04	60.96	2.14	63.84	2.62	78.19	1.41	42.10	1.31	38.99	1.31	38.99	2.03	60.59
7	A/185	0.70	Jabalia	1.93	49.18	0.44	13.04	1.47	43.86	2.04	60.96	2.14	63.84	2.62	78.19	1.41	42.10	1.31	38.99	1.31	38.99	2.03	60.59
8	D/71	0.70	Jabalia	1.93	49.18	0.44	13.04	1.47	43.86	2.04	60.96	2.14	63.84	2.62	78.19	1.41	42.10	1.31	38.99	1.31	38.99	2.03	60.59
9	C/127	0.70	Bait hanon	1.93	49.18	0.58	18.14	1.52	46.16	0.00	56.00	0.58	62.29	1.69	92.11	1.40	41.35	1.36	40.49	1.39	41.64	1.93	57.56
10	D/74	0.70	Jabalia	1.93	49.18	0.44	13.04	1.47	43.86	2.04	60.96	2.14	63.84	2.62	78.19	1.41	42.10	1.31	38.99	1.31	38.99	2.03	60.59
11	D/70	0.70	Jabalia	1.93	49.18	0.44	13.04	1.47	43.86	2.04	60.96	2.14	63.84	2.62	78.19	1.41	42.10	1.31	38.99	1.31	38.99	2.03	60.59
12	D/69	0.70	Jabalia	1.93	49.18	0.44	13.04	1.47	43.86	2.04	60.96	2.14	63.84	2.62	78.19	1.41	42.10	1.31	38.99	1.31	38.99	2.03	60.59
13	E/6	0.70	Jabalia	1.93	49.18	0.44	13.04	1.47	43.86	2.04	60.96	2.14	63.84	2.62	78.19	1.41	42.10	1.31	38.99	1.31	38.99	2.03	60.59
14	E/142	0.70	Jabalia	1.93	49.18	0.44	13.04	1.47	43.86	2.04	60.96	2.14	63.84	2.62	78.19	1.41	42.10	1.31	38.99	1.31	38.99	2.03	60.59
15	D/68	0.70	Jabalia	1.93	49.18	0.44	13.04	1.47	43.86	2.04	60.96	2.14	63.84	2.62	78.19	1.41	42.10	1.31	38.99	1.31	38.99	2.03	60.59
16	D/60	0.70	Jabalia	1.93	49.18	0.44	13.04	1.47	43.86	2.04	60.96	2.14	63.84	2.62	78.19	1.41	42.10	1.31	38.99	1.31	38.99	2.03	60.59
17	C/79	0.35	Bait hanon	0.96	24.59	0.29	9.07	0.76	23.08	0.00	28.00	0.29	31.14	0.85	46.05	0.70	20.67	0.68	20.25	0.70	20.82	0.96	28.78
18	E/4	0.70	Jabalia	1.93	49.18	0.44	13.04	1.47	43.86	2.04	60.96	2.14	63.84	2.62	78.19	1.41	42.10	1.31	38.99	1.31	38.99	2.03	60.59
19	E/154	0.70	Jabalia	1.93	49.18	0.44	13.04	1.47	43.86	2.04	60.96	2.14	63.84	2.62	78.19	1.41	42.10	1.31	38.99	1.31	38.99	2.03	60.59
20	C/128	0.35	Bait hanon	0.96	24.59	0.29	9.07	0.76	23.08	0.00	28.00	0.29	31.14	0.85	46.05	0.70	20.67	0.68	20.25	0.70	20.82	0.96	28.78
21	E/157	0.70	Jabalia	1.93	49.18	0.44	13.04	1.47	43.86	2.04	60.96	2.14	63.84	2.62	78.19	1.41	42.10	1.31	38.99	1.31	38.99	2.03	60.59
22	E/156	0.70	Jabalia	1.93	49.18	0.44	13.04	1.47	43.86	2.04	60.96	2.14	63.84	2.62	78.19	1.41	42.10	1.31	38.99	1.31	38.99	2.03	60.59
23	E/90	0.70	Jabalia	1.93	49.18	0.44	13.04	1.47	43.86	2.04	60.96	2.14	63.84	2.62	78.19	1.41	42.10	1.31	38.99	1.31	38.99	2.03	60.59
24	R/162B	0.70	Shati	1.42	32.84	0.23	16.31	0.88	49.16	0.19	54.40	0.64	58.81	2.10	71.28	1.07	39.39	1.12	33.48	1.20	35.81	1.77	52.94
25	C/76	0.35	Bait hanon	0.96	24.59	0.29	9.07	0.76	23.08	0.00	28.00	0.29	31.14	0.85	46.05	0.70	20.67	0.68	20.25	0.70	20.82	0.96	28.78
26	R/162L	0.70	Gaza city	1.35	39.96	0.27	18.19	1.03	40.81	0.14	56.46	0.37	61.79	2.18	71.65	1.07	40.79	1.19	35.67	1.22	36.39	1.89	56.58
27	R/162LA	0.70	Gaza city	1.35	39.96	0.27	18.19	1.03	40.81	0.14	56.46	0.37	61.79	2.18	71.65	1.07	40.79	1.19	35.67	1.22	36.39	1.89	56.58
28	R/162G	0.70	Jabalia	1.93	49.18	0.44	13.04	1.47	43.86	2.04	60.96	2.14	63.84	2.62	78.19	1.41	42.10	1.31	38.99	1.31	38.99	2.03	60.59
29	R/162HA	0.70	Gaza city	1.35	39.96	0.27	18.19	1.03	40.81	0.14	56.46	0.37	61.79	2.18	71.65	1.07	40.79	1.19	35.67	1.22	36.39	1.89	56.58

1	Ag No	Rech. Coff.	Station	1997-A	1997-B	1998-A	1998-B	1999-A	1999-B	2000-A	2000-B	2001-A	2001-B	2002-A	2002-B	2003-A	2003-B	2004-A	2004-B	2005-A	2005-B	2006-A	2006-B
30	R/162H	0.70	Gaza city	1.35	39.96	0.27	18.19	1.03	40.81	0.14	56.46	0.37	61.79	2.18	71.65	1.07	40.79	1.19	35.67	1.22	36.39	1.89	56.58
31	Q/68	0.70	Tuffah	1.35	39.96	0.42	12.64	1.35	40.32	2.02	60.21	2.28	68.22	2.47	73.77	1.63	48.67	1.31	38.99	1.37	41.03	2.06	61.58
32	R/112	0.70	Gaza city	1.35	39.96	0.27	18.19	1.03	40.81	0.14	56.46	0.37	61.79	2.18	71.65	1.07	40.79	1.19	35.67	1.22	36.39	1.89	56.58
33	R/25A	0.70	Tuffah	1.35	39.96	0.42	12.64	1.35	40.32	2.02	60.21	2.28	68.22	2.47	73.77	1.63	48.67	1.31	38.99	1.37	41.03	2.06	61.58
34	R/25B	0.70	Tuffah	1.35	39.96	0.42	12.64	1.35	40.32	2.02	60.21	2.28	68.22	2.47	73.77	1.63	48.67	1.31	38.99	1.37	41.03	2.06	61.58
35	R/113	0.70	Gaza city	1.35	39.96	0.27	18.19	1.03	40.81	0.14	56.46	0.37	61.79	2.18	71.65	1.07	40.79	1.19	35.67	1.22	36.39	1.89	56.58
36	R/25D	0.70	Tuffah	1.35	39.96	0.42	12.64	1.35	40.32	2.02	60.21	2.28	68.22	2.47	73.77	1.63	48.67	1.31	38.99	1.37	41.03	2.06	61.58
37	R/25C	0.70	Tuffah	1.35	39.96	0.42	12.64	1.35	40.32	2.02	60.21	2.28	68.22	2.47	73.77	1.63	48.67	1.31	38.99	1.37	41.03	2.06	61.58
38	R/254	0.70	Gaza city	1.35	39.96	0.27	18.19	1.03	40.81	0.14	56.46	0.37	61.79	2.18	71.65	1.07	40.79	1.19	35.67	1.22	36.39	1.89	56.58
39	R/265	0.70	Gaza city	1.35	39.96	0.27	18.19	1.03	40.81	0.14	56.46	0.37	61.79	2.18	71.65	1.07	40.79	1.19	35.67	1.22	36.39	1.89	56.58
40	R/74	0.35	Tuffah	0.68	19.98	0.21	6.32	0.68	20.16	1.01	30.11	1.14	34.11	1.24	36.89	0.81	24.33	0.65	19.50	0.69	20.52	1.03	30.79
41	R/75	0.35	Tuffah	0.68	19.98	0.21	6.32	0.68	20.16	1.01	30.11	1.14	34.11	1.24	36.89	0.81	24.33	0.65	19.50	0.69	20.52	1.03	30.79
42	S/69	0.25	Bair El balah	0.29	9.40	0.35	4.77	0.38	10.69	0.00	22.65	0.29	15.86	0.42	14.84	0.40	13.04	0.47	13.93	0.35	10.36	0.56	16.85
43	J/146	0.25	Bair El balah	0.29	9.40	0.35	4.77	0.38	10.69	0.00	22.65	0.29	15.86	0.42	14.84	0.40	13.04	0.47	13.93	0.35	10.36	0.56	16.85
44	L/179	0.35	Khan Younis	0.35	13.67	0.08	3.66	0.82	11.37	0.00	21.50	0.65	17.48	0.70	16.64	0.61	11.94	0.70	21.05	0.51	15.24	0.48	14.22
45	L/159A	0.70	Khan Younis	0.70	27.34	0.15	7.33	1.63	22.74	0.00	42.99	1.31	34.97	1.40	33.27	1.21	23.88	1.41	42.11	1.02	30.48	0.95	28.45
46	L/159	0.70	Khan Younis	0.70	27.34	0.15	7.33	1.63	22.74	0.00	42.99	1.31	34.97	1.40	33.27	1.21	23.88	1.41	42.11	1.02	30.48	0.95	28.45
47	L/87	0.35	Khan Younis	0.35	13.67	0.08	3.66	0.82	11.37	0.00	21.50	0.65	17.48	0.70	16.64	0.61	11.94	0.70	21.05	0.51	15.24	0.48	14.22
48	L/127	0.35	Khan Younis	0.35	13.67	0.08	3.66	0.82	11.37	0.00	21.50	0.65	17.48	0.70	16.64	0.61	11.94	0.70	21.05	0.51	15.24	0.48	14.22
49	L/43	0.35	Khan Younis	0.35	13.67	0.08	3.66	0.82	11.37	0.00	21.50	0.65	17.48	0.70	16.64	0.61	11.94	0.70	21.05	0.51	15.24	0.48	14.22
50	L/176	0.35	Khan Younis	0.35	13.67	0.08	3.66	0.82	11.37	0.00	21.50	0.65	17.48	0.70	16.64	0.61	11.94	0.70	21.05	0.51	15.24	0.48	14.22
51	L/41	0.25	Khan Younis	0.25	9.76	0.05	2.62	0.58	8.12	0.00	15.35	0.47	12.49	0.50	11.88	0.43	8.53	0.50	15.04	0.36	10.89	0.34	10.16
52	P/139	0.70	Rafah	0.47	25.90	0.18	5.89	1.28	23.35	0.00	34.30	1.63	27.27	0.93	23.43	2.33	20.30	1.36	40.66	0.77	22.92	0.85	25.40
53	P/144	0.70	Rafah	0.47	25.90	0.18	5.89	1.28	23.35	0.00	34.30	1.63	27.27	0.93	23.43	2.33	20.30	1.36	40.66	0.77	22.92	0.85	25.40
54	P/145	0.70	Rafah	0.47	25.90	0.18	5.89	1.28	23.35	0.00	34.30	1.63	27.27	0.93	23.43	2.33	20.30	1.36	40.66	0.77	22.92	0.85	25.40
55	P/138	0.70	Rafah	0.47	25.90	0.18	5.89	1.28	23.35	0.00	34.30	1.63	27.27	0.93	23.43	2.33	20.30	1.36	40.66	0.77	22.92	0.85	25.40
56	P/124	0.70	Rafah	0.47	25.90	0.18	5.89	1.28	23.35	0.00	34.30	1.63	27.27	0.93	23.43	2.33	20.30	1.36	40.66	0.77	22.92	0.85	25.40
57	P/15	0.35	Rafah	0.23	12.95	0.09	2.95	0.64	11.67	0.00	17.15	0.82	13.63	0.47	11.71	1.17	10.15	0.68	20.33	0.38	11.46	0.43	12.70

ANNEX 4: Abstraction hourly rate (m^3/hour) for all study wells from 1997 to 2003

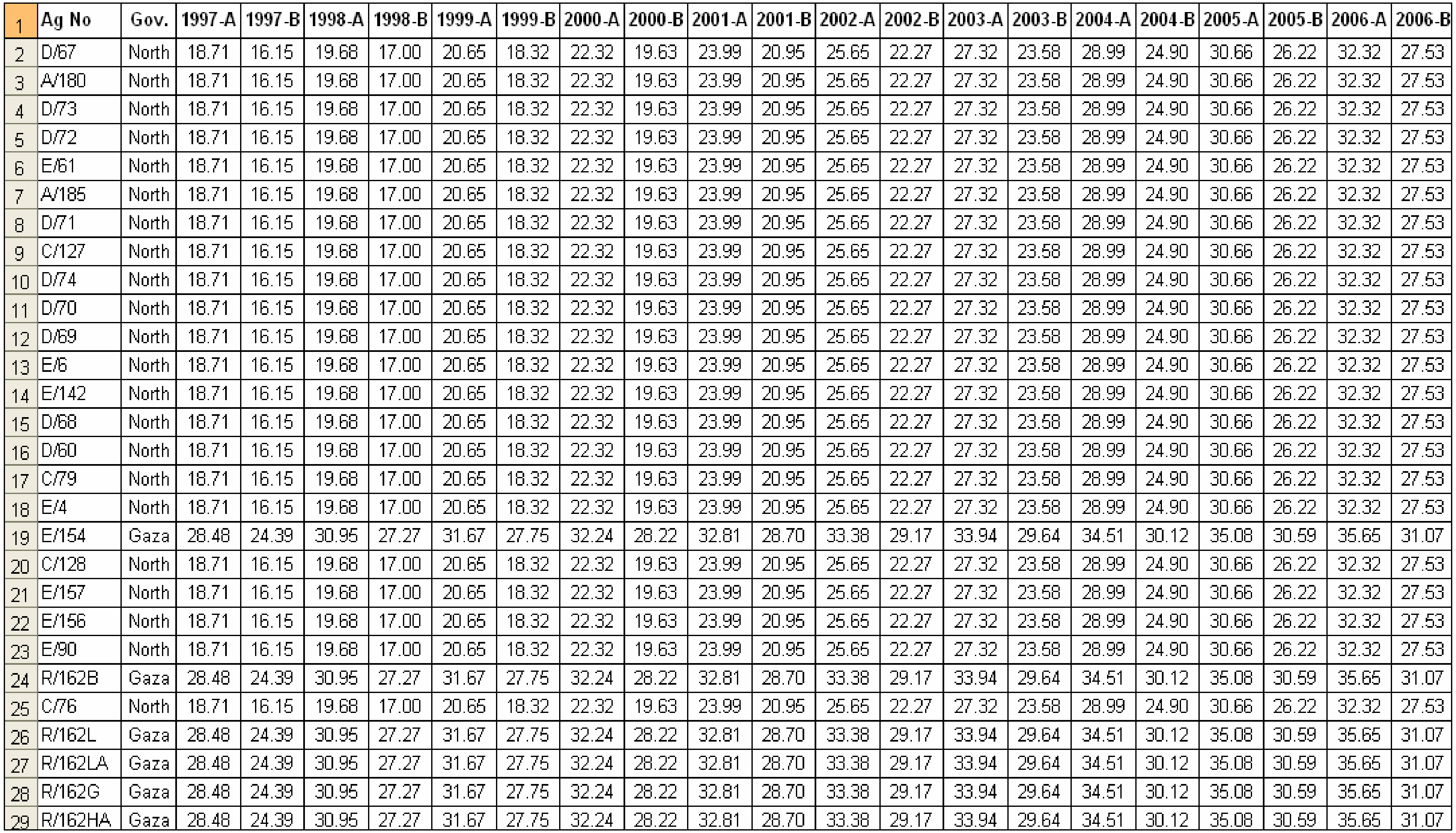


1		1997-A	1997-B	1998-A	1998-B	1999-A	1999-B	2000-A	2000-B	2001-A	2001-B	2002-A	2002-A	2002-B	2002-B	2003-A	Ave. A	Ave. B
2	D/67	48.23	27.66	63.76	57.74	24.86	23.07	33.11	30.00	48.20	31.39	185,887	43.03	133,477	30.90	48.39	43.53	33.46
3	A/180	64.63	30.42	28.58	8.15	5.56	5.56	14.56	43.37	69.11	45.14	275,280	63.72	247,820	57.37	83.71	41.03	31.67
4	D/73	0.00	0.00	50.45	53.36	102.76	68.30	102.25	73.93	103.72	84.23	543,195	125.74	414,280	95.90	128.11	80.82	62.62
5	D/72	0.00	0.00	99.87	65.44	62.58	189.23	173.83	166.51	174.81	166.99	746,689	172.84	744,872	172.42	197.77	113.99	126.77
6	E/61	34.06	30.42	28.58	8.15	5.56	5.56	14.56	12.38	149.77	28.71	98,510	22.80	0.00	0.00	0.00	25.89	14.20
7	A/185	172.86	150.89	124.94	83.74	132.13	116.28	111.46	112.72	144.95	131.04	759,620	175.84	612,320	141.74	246.55	143.70	122.73
8	D/71	0.00	0.00	149.70	126.59	102.79	193.38	201.56	184.56	185.71	139.67	864,964	200.22	928,300	214.88	237.57	140.00	143.18
9	C/127	61.36	34.87	64.11	52.16	60.84	43.95	62.57	42.50	68.88	60.65	316,825	73.34	285,113	66.00	73.90	65.18	50.02
10	D/74	139.37	142.48	162.24	150.84	196.21	191.38	155.89	101.11	166.44	131.79	756,358	175.08	484,750	112.21	119.88	165.88	138.30
11	D/70	0.00	0.00	168.94	170.89	179.62	155.96	158.07	152.29	151.15	128.92	600,063	138.90	545,000	126.16	150.54	132.78	122.37
12	D/69	0.00	0.00	175.51	171.86	171.94	173.28	168.69	181.04	170.48	145.33	736,638	170.52	690,490	159.84	188.73	142.85	138.56
13	E/6	0.00	0.00	7.52	5.21	10.87	6.22	84.86	81.90	86.92	59.11	349,090	80.81	266,220	61.63	16.47	45.16	35.68
14	E/142	10.25	0.95	53.47	49.38	16.35	8.98	22.34	21.64	31.26	36.28	191,010	44.22	162,260	37.56	46.30	29.65	25.80
15	D/68	177.38	172.71	172.64	159.30	141.80	178.39	188.65	174.68	177.29	182.67	826,704	191.37	813,500	188.31	208.75	174.85	176.01
16	D/60	56.81	55.78	54.81	44.67	75.13	22.55	81.92	70.07	78.11	80.49	441,420	102.18	381,740	88.37	108.95	74.83	60.32
17	C/79	0.00	0.00	0.00	0.00	4.57	38.59	39.24	13.95	33.80	24.25	226,300	52.38	75,707	17.52	6.77	21.67	15.72
18	E/4	81.63	76.91	121.02	109.49	94.34	85.69	78.89	32.85	60.11	37.04	180,200	41.71	192,010	44.45	58.15	79.62	64.40
19	E/154	180.31	186.47	157.06	178.48	167.99	175.27	174.27	140.29	149.18	127.42	569,212	131.76	550,661	127.47	154.59	160.10	155.90
20	C/128	118.65	92.84	138.27	99.71	120.01	72.59	101.76	82.65	107.64	91.95	425,770	98.56	390,520	90.40	103.49	114.15	88.36
21	E/157	198.43	191.25	182.99	147.20	176.99	174.57	167.82	139.73	159.68	165.42	707,300	163.73	646,900	149.75	176.15	174.94	161.32
22	E/156	151.75	96.79	77.74	133.13	180.28	77.74	159.69	118.70	163.91	151.73	847,082	196.08	776,382	179.72	199.56	154.91	126.30
23	E/90	74.01	94.07	153.41	143.02	195.00	183.02	175.07	130.65	177.93	153.13	815,749	188.83	720,034	166.67	179.28	160.71	145.09
24	R/162B	188.15	21.17	31.23	0.00	30.34	0.00	150.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	51.70	3.53
25	C/76	45.16	0.00	46.01	4.56	2.61	13.91	19.54	10.89	26.05	17.76	96,810	22.41	72,050	16.68	17.86	26.96	12.76
26	R/162L	188.85	178.43	206.95	152.31	193.38	191.77	200.24	186.35	184.03	139.80	720,952	166.89	662,400	153.33	186.49	190.06	167.00
27	R/162LA	126.23	131.76	206.95	77.75	125.66	117.04	150.47	144.97	154.83	181.01	668,568	154.76	644,700	149.24	141.22	153.15	133.63
28	R/162G	196.53	194.06	187.88	141.08	172.83	164.50	152.97	154.18	183.70	134.01	715,700	165.67	769,600	178.15	214.81	176.60	161.00
29	R/162HA	175.42	196.41	195.39	185.40	178.69	160.81	155.29	93.99	85.40	95.73	771,516	178.59	655,857	151.82	205.72	161.46	147.36

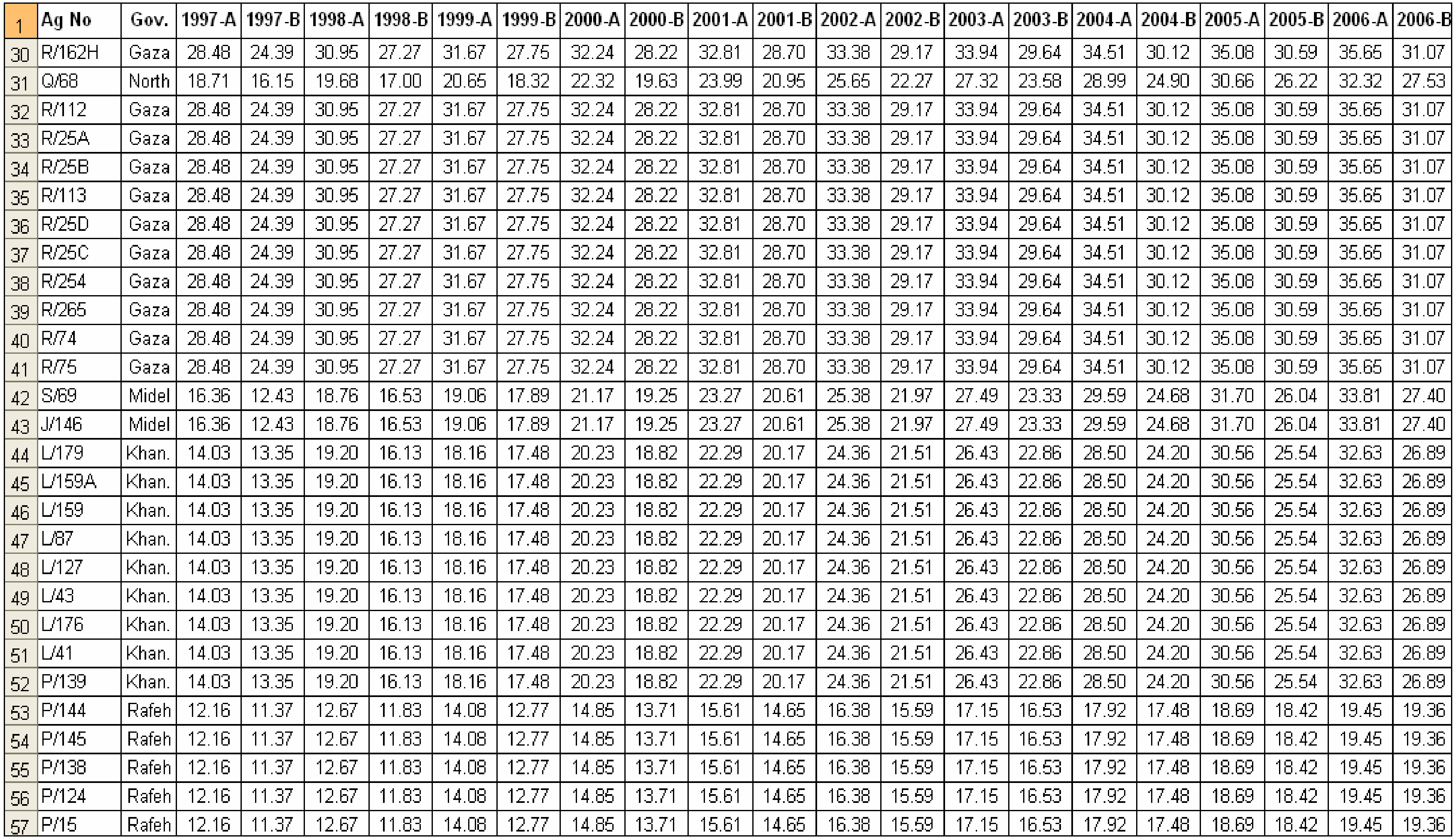


1		1997-A	1997-B	1998-A	1998-B	1999-A	1999-B	2000-A	2000-B	2001-A	2001-B	2002-A	2002-A	2002-B	2002-B	2003-A	Ave. A	Ave. B
30	R/162H	108.47	82.10	149.87	163.99	175.57	105.87	134.68	132.42	139.84	125.31	564,745	130.73	570,100	131.97	157.41	139.86	123.61
31	Q/68	0.00	0.00	0.00	0.00	42.97	169.74	209.71	199.26	216.45	203.48	999,403	231.34	860,294	199.14	254.94	116.75	128.60
32	R/112	87.85	21.83	74.09	52.47	67.05	15.61	60.01	11.36	58.80	15.32	248,612	57.55	40,967	9.48	28.77	67.56	21.01
33	R/25A	116.88	154.96	149.51	51.36	134.87	135.42	126.27	118.81	121.43	117.71	546,616	126.53	521,386	120.69	130.61	129.25	116.49
34	R/25B	190.16	0.00	192.39	138.94	56.86	79.80	183.94	132.69	189.54	144.20	672,868	155.76	558,877	129.37	198.60	161.44	104.17
35	R/113	0.00	0.00	52.17	141.07	0.00	0.00	76.55	73.24	73.73	69.27	324,690	75.16	331,066	76.64	90.93	46.27	60.04
36	R/25D	181.30	153.48	129.32	103.42	90.20	147.94	155.85	175.96	193.60	188.49	902,605	208.94	790,000	182.87	213.99	159.87	158.69
37	R/25C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.53	48.99	1.34	6,895	1.60	1,020	0.24	8.91	8.43	1.35
38	R/254	117.92	106.78	97.52	58.12	61.23	90.55	116.30	72.83	107.34	82.19	451,929	104.61	317,760	73.56	75.57	100.82	80.67
39	R/265	0.00	0.00	73.42	108.41	0.00	0.00	0.00	42.78	43.25	48.40	229,495	53.12	204,178	47.26	55.68	28.30	41.14
40	R/74	31.83	17.28	25.21	15.68	44.78	9.59	16.72	1.78	19.15	9.28	66,601	15.42	35,229	8.15	8.37	25.52	10.29
41	R/75	0.00	0.00	82.67	0.00	0.00	0.00	0.00	14.43	50.15	8.01	227,370	52.63	52,990	12.27	47.74	30.91	5.78
42	S/69	96.78	92.01	92.18	77.88	67.25	81.13	75.49	53.77	47.94	45.76	205,100	47.48	245,630	56.86	89.84	71.19	67.90
43	J/146	95.09	40.88	111.06	106.32	94.09	107.43	109.91	103.08	103.66	100.65	422,700	97.85	402,300	93.13	104.75	101.94	91.91
44	L/179	63.56	0.00	57.53	44.19	51.77	51.97	65.82	55.89	64.65	58.95	285,890	66.18	280,010	64.82	60.87	61.59	45.97
45	L/159A	0.00	0.00	57.82	53.31	0.00	0.00	71.56	64.01	71.20	73.38	332,579	76.99	411,353	95.22	118.75	46.26	47.65
46	L/159	68.65	64.75	53.53	47.51	49.32	54.34	57.96	52.80	58.94	52.10	224,615	51.99	284,552	65.87	76.88	56.73	56.23
47	L/87	80.67	79.61	64.32	85.88	24.31	46.93	58.43	49.04	64.78	58.68	303,683	70.30	298,207	69.03	84.09	60.47	64.86
48	L/127	45.09	34.78	59.26	65.40	65.85	55.57	79.55	71.44	95.31	87.59	382,463	88.53	348,289	80.62	79.99	72.27	65.90
49	L/43	61.24	60.97	69.84	60.81	60.43	66.25	66.25	43.42	70.12	58.35	316,107	73.17	304,956	70.59	116.65	66.84	60.07
50	L/176	149.77	108.47	138.78	108.77	117.05	116.06	121.86	117.37	139.84	144.75	580,069	134.28	515,286	119.28	140.09	133.60	119.12
51	L/41	6.94	32.55	35.93	35.93	64.47	61.48	76.32	70.86	78.70	75.61	330,715	76.55	316,783	73.33	82.56	56.49	58.29
52	P/139	85.48	55.90	27.98	5.86	6.46	6.07	10.55	10.49	14.58	11.46	30,000	6.94	30,000	6.94	7.64	25.33	16.12
53	P/144	108.24	121.13	100.50	161.97	164.83	152.64	140.86	128.28	126.24	116.66	615,167	142.40	448,110	103.73	119.51	130.51	130.73
54	P/145	0.00	0.00	63.60	98.27	98.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.01	16.38
55	P/138	3.60	12.24	28.72	29.03	59.48	27.59	50.10	53.51	61.80	56.09	271,776	62.91	257,500	59.61	72.31	44.43	39.68
56	P/124	166.19	136.22	115.56	117.74	151.81	192.70	185.49	174.56	176.74	181.50	809,500	187.38	794,800	183.98	198.03	163.86	164.45
57	P/15	130.46	0.15	100.19	58.63	63.44	69.51	90.29	48.39	86.36	69.90	388,402	89.91	333,900	77.29	86.87	93.44	53.98

ANNEX 5 : Abstraction average rate (mm/m^2/month) for areas of study wells from 1997 to 2006



1	Ag No	Gov.	1997-A	1997-B	1998-A	1998-B	1999-A	1999-B	2000-A	2000-B	2001-A	2001-B	2002-A	2002-B	2003-A	2003-B	2004-A	2004-B	2005-A	2005-B	2006-A	2006-B
2	D/67	North	18.71	16.15	19.68	17.00	20.65	18.32	22.32	19.63	23.99	20.95	25.65	22.27	27.32	23.58	28.99	24.90	30.66	26.22	32.32	27.53
3	A/180	North	18.71	16.15	19.68	17.00	20.65	18.32	22.32	19.63	23.99	20.95	25.65	22.27	27.32	23.58	28.99	24.90	30.66	26.22	32.32	27.53
4	D/73	North	18.71	16.15	19.68	17.00	20.65	18.32	22.32	19.63	23.99	20.95	25.65	22.27	27.32	23.58	28.99	24.90	30.66	26.22	32.32	27.53
5	D/72	North	18.71	16.15	19.68	17.00	20.65	18.32	22.32	19.63	23.99	20.95	25.65	22.27	27.32	23.58	28.99	24.90	30.66	26.22	32.32	27.53
6	E/61	North	18.71	16.15	19.68	17.00	20.65	18.32	22.32	19.63	23.99	20.95	25.65	22.27	27.32	23.58	28.99	24.90	30.66	26.22	32.32	27.53
7	A/185	North	18.71	16.15	19.68	17.00	20.65	18.32	22.32	19.63	23.99	20.95	25.65	22.27	27.32	23.58	28.99	24.90	30.66	26.22	32.32	27.53
8	D/71	North	18.71	16.15	19.68	17.00	20.65	18.32	22.32	19.63	23.99	20.95	25.65	22.27	27.32	23.58	28.99	24.90	30.66	26.22	32.32	27.53
9	C/127	North	18.71	16.15	19.68	17.00	20.65	18.32	22.32	19.63	23.99	20.95	25.65	22.27	27.32	23.58	28.99	24.90	30.66	26.22	32.32	27.53
10	D/74	North	18.71	16.15	19.68	17.00	20.65	18.32	22.32	19.63	23.99	20.95	25.65	22.27	27.32	23.58	28.99	24.90	30.66	26.22	32.32	27.53
11	D/70	North	18.71	16.15	19.68	17.00	20.65	18.32	22.32	19.63	23.99	20.95	25.65	22.27	27.32	23.58	28.99	24.90	30.66	26.22	32.32	27.53
12	D/69	North	18.71	16.15	19.68	17.00	20.65	18.32	22.32	19.63	23.99	20.95	25.65	22.27	27.32	23.58	28.99	24.90	30.66	26.22	32.32	27.53
13	E/6	North	18.71	16.15	19.68	17.00	20.65	18.32	22.32	19.63	23.99	20.95	25.65	22.27	27.32	23.58	28.99	24.90	30.66	26.22	32.32	27.53
14	E/142	North	18.71	16.15	19.68	17.00	20.65	18.32	22.32	19.63	23.99	20.95	25.65	22.27	27.32	23.58	28.99	24.90	30.66	26.22	32.32	27.53
15	D/68	North	18.71	16.15	19.68	17.00	20.65	18.32	22.32	19.63	23.99	20.95	25.65	22.27	27.32	23.58	28.99	24.90	30.66	26.22	32.32	27.53
16	D/60	North	18.71	16.15	19.68	17.00	20.65	18.32	22.32	19.63	23.99	20.95	25.65	22.27	27.32	23.58	28.99	24.90	30.66	26.22	32.32	27.53
17	C/79	North	18.71	16.15	19.68	17.00	20.65	18.32	22.32	19.63	23.99	20.95	25.65	22.27	27.32	23.58	28.99	24.90	30.66	26.22	32.32	27.53
18	E/4	North	18.71	16.15	19.68	17.00	20.65	18.32	22.32	19.63	23.99	20.95	25.65	22.27	27.32	23.58	28.99	24.90	30.66	26.22	32.32	27.53
19	E/154	Gaza	28.48	24.39	30.95	27.27	31.67	27.75	32.24	28.22	32.81	28.70	33.38	29.17	33.94	29.64	34.51	30.12	35.08	30.59	35.65	31.07
20	C/128	North	18.71	16.15	19.68	17.00	20.65	18.32	22.32	19.63	23.99	20.95	25.65	22.27	27.32	23.58	28.99	24.90	30.66	26.22	32.32	27.53
21	E/157	North	18.71	16.15	19.68	17.00	20.65	18.32	22.32	19.63	23.99	20.95	25.65	22.27	27.32	23.58	28.99	24.90	30.66	26.22	32.32	27.53
22	E/156	North	18.71	16.15	19.68	17.00	20.65	18.32	22.32	19.63	23.99	20.95	25.65	22.27	27.32	23.58	28.99	24.90	30.66	26.22	32.32	27.53
23	E/90	North	18.71	16.15	19.68	17.00	20.65	18.32	22.32	19.63	23.99	20.95	25.65	22.27	27.32	23.58	28.99	24.90	30.66	26.22	32.32	27.53
24	R/162B	Gaza	28.48	24.39	30.95	27.27	31.67	27.75	32.24	28.22	32.81	28.70	33.38	29.17	33.94	29.64	34.51	30.12	35.08	30.59	35.65	31.07
25	C/76	North	18.71	16.15	19.68	17.00	20.65	18.32	22.32	19.63	23.99	20.95	25.65	22.27	27.32	23.58	28.99	24.90	30.66	26.22	32.32	27.53
26	R/162L	Gaza	28.48	24.39	30.95	27.27	31.67	27.75	32.24	28.22	32.81	28.70	33.38	29.17	33.94	29.64	34.51	30.12	35.08	30.59	35.65	31.07
27	R/162LA	Gaza	28.48	24.39	30.95	27.27	31.67	27.75	32.24	28.22	32.81	28.70	33.38	29.17	33.94	29.64	34.51	30.12	35.08	30.59	35.65	31.07
28	R/162G	Gaza	28.48	24.39	30.95	27.27	31.67	27.75	32.24	28.22	32.81	28.70	33.38	29.17	33.94	29.64	34.51	30.12	35.08	30.59	35.65	31.07
29	R/162HA	Gaza	28.48	24.39	30.95	27.27	31.67	27.75	32.24	28.22	32.81	28.70	33.38	29.17	33.94	29.64	34.51	30.12	35.08	30.59	35.65	31.07



1	Ag No	Gov.	1997-A	1997-B	1998-A	1998-B	1999-A	1999-B	2000-A	2000-B	2001-A	2001-B	2002-A	2002-B	2003-A	2003-B	2004-A	2004-B	2005-A	2005-B	2006-A	2006-B
30	R/162H	Gaza	28.48	24.39	30.95	27.27	31.67	27.75	32.24	28.22	32.81	28.70	33.38	29.17	33.94	29.64	34.51	30.12	35.08	30.59	35.65	31.07
31	Q/68	North	18.71	16.15	19.68	17.00	20.65	18.32	22.32	19.63	23.99	20.95	25.65	22.27	27.32	23.58	28.99	24.90	30.66	26.22	32.32	27.53
32	R/112	Gaza	28.48	24.39	30.95	27.27	31.67	27.75	32.24	28.22	32.81	28.70	33.38	29.17	33.94	29.64	34.51	30.12	35.08	30.59	35.65	31.07
33	R/25A	Gaza	28.48	24.39	30.95	27.27	31.67	27.75	32.24	28.22	32.81	28.70	33.38	29.17	33.94	29.64	34.51	30.12	35.08	30.59	35.65	31.07
34	R/25B	Gaza	28.48	24.39	30.95	27.27	31.67	27.75	32.24	28.22	32.81	28.70	33.38	29.17	33.94	29.64	34.51	30.12	35.08	30.59	35.65	31.07
35	R/113	Gaza	28.48	24.39	30.95	27.27	31.67	27.75	32.24	28.22	32.81	28.70	33.38	29.17	33.94	29.64	34.51	30.12	35.08	30.59	35.65	31.07
36	R/25D	Gaza	28.48	24.39	30.95	27.27	31.67	27.75	32.24	28.22	32.81	28.70	33.38	29.17	33.94	29.64	34.51	30.12	35.08	30.59	35.65	31.07
37	R/25C	Gaza	28.48	24.39	30.95	27.27	31.67	27.75	32.24	28.22	32.81	28.70	33.38	29.17	33.94	29.64	34.51	30.12	35.08	30.59	35.65	31.07
38	R/254	Gaza	28.48	24.39	30.95	27.27	31.67	27.75	32.24	28.22	32.81	28.70	33.38	29.17	33.94	29.64	34.51	30.12	35.08	30.59	35.65	31.07
39	R/265	Gaza	28.48	24.39	30.95	27.27	31.67	27.75	32.24	28.22	32.81	28.70	33.38	29.17	33.94	29.64	34.51	30.12	35.08	30.59	35.65	31.07
40	R/74	Gaza	28.48	24.39	30.95	27.27	31.67	27.75	32.24	28.22	32.81	28.70	33.38	29.17	33.94	29.64	34.51	30.12	35.08	30.59	35.65	31.07
41	R/75	Gaza	28.48	24.39	30.95	27.27	31.67	27.75	32.24	28.22	32.81	28.70	33.38	29.17	33.94	29.64	34.51	30.12	35.08	30.59	35.65	31.07
42	S/69	Midel	16.36	12.43	18.76	16.53	19.06	17.89	21.17	19.25	23.27	20.61	25.38	21.97	27.49	23.33	29.59	24.68	31.70	26.04	33.81	27.40
43	J/146	Midel	16.36	12.43	18.76	16.53	19.06	17.89	21.17	19.25	23.27	20.61	25.38	21.97	27.49	23.33	29.59	24.68	31.70	26.04	33.81	27.40
44	L/179	Khan.	14.03	13.35	19.20	16.13	18.16	17.48	20.23	18.82	22.29	20.17	24.36	21.51	26.43	22.86	28.50	24.20	30.56	25.54	32.63	26.89
45	L/159A	Khan.	14.03	13.35	19.20	16.13	18.16	17.48	20.23	18.82	22.29	20.17	24.36	21.51	26.43	22.86	28.50	24.20	30.56	25.54	32.63	26.89
46	L/159	Khan.	14.03	13.35	19.20	16.13	18.16	17.48	20.23	18.82	22.29	20.17	24.36	21.51	26.43	22.86	28.50	24.20	30.56	25.54	32.63	26.89
47	L/87	Khan.	14.03	13.35	19.20	16.13	18.16	17.48	20.23	18.82	22.29	20.17	24.36	21.51	26.43	22.86	28.50	24.20	30.56	25.54	32.63	26.89
48	L/127	Khan.	14.03	13.35	19.20	16.13	18.16	17.48	20.23	18.82	22.29	20.17	24.36	21.51	26.43	22.86	28.50	24.20	30.56	25.54	32.63	26.89
49	L/43	Khan.	14.03	13.35	19.20	16.13	18.16	17.48	20.23	18.82	22.29	20.17	24.36	21.51	26.43	22.86	28.50	24.20	30.56	25.54	32.63	26.89
50	L/176	Khan.	14.03	13.35	19.20	16.13	18.16	17.48	20.23	18.82	22.29	20.17	24.36	21.51	26.43	22.86	28.50	24.20	30.56	25.54	32.63	26.89
51	L/41	Khan.	14.03	13.35	19.20	16.13	18.16	17.48	20.23	18.82	22.29	20.17	24.36	21.51	26.43	22.86	28.50	24.20	30.56	25.54	32.63	26.89
52	P/139	Khan.	14.03	13.35	19.20	16.13	18.16	17.48	20.23	18.82	22.29	20.17	24.36	21.51	26.43	22.86	28.50	24.20	30.56	25.54	32.63	26.89
53	P/144	Rafeh	12.16	11.37	12.67	11.83	14.08	12.77	14.85	13.71	15.61	14.65	16.38	15.59	17.15	16.53	17.92	17.48	18.69	18.42	19.45	19.36
54	P/145	Rafeh	12.16	11.37	12.67	11.83	14.08	12.77	14.85	13.71	15.61	14.65	16.38	15.59	17.15	16.53	17.92	17.48	18.69	18.42	19.45	19.36
55	P/138	Rafeh	12.16	11.37	12.67	11.83	14.08	12.77	14.85	13.71	15.61	14.65	16.38	15.59	17.15	16.53	17.92	17.48	18.69	18.42	19.45	19.36
56	P/124	Rafeh	12.16	11.37	12.67	11.83	14.08	12.77	14.85	13.71	15.61	14.65	16.38	15.59	17.15	16.53	17.92	17.48	18.69	18.42	19.45	19.36
57	P/15	Rafeh	12.16	11.37	12.67	11.83	14.08	12.77	14.85	13.71	15.61	14.65	16.38	15.59	17.15	16.53	17.92	17.48	18.69	18.42	19.45	19.36

ANNEX 6 : Data matrix of ANN model

Time phase	Well	Cl_o	R	Q	Qr	Ot	Wl	Dw	Th	Ds	Cl_f	$Cl_{f\text{-}}$ predicted
1997-A	D/67	78.0	2.14	48.23	18.71	20	-2	79	80	2.4	55.0	95.7
1997-A	E/61	66.0	1.93	34.06	18.71	23	-1	43	40	1.3	145.0	120.1
1997-A	A/185	70.0	1.93	172.86	18.71	14	-2	80	95	3.6	100.0	61.2
1997-A	C/127	92.0	1.93	61.36	18.71	32	0	75	115	5.6	100.0	85.9
1997-A	D/74	56.0	1.93	139.37	18.71	0	-2	81	50	2.0	65.0	74.9
1997-A	D/68	92.0	1.93	177.38	18.71	9	-2	72	58	2.6	122.0	101.6
1997-A	D/60	142.0	1.93	56.81	18.71	38	-2	45	43	3.3	129.0	183.4
1997-A	C/79	427.0	0.96	0.00	18.71	27	0	64	90	6.4	384.0	438.6
1997-A	E/4	108.0	1.93	81.63	18.71	37	-1	34	124	4.7	100.0	94.4
1997-A	E/154	189.0	1.93	180.31	28.48	22	-2	92	50	1.7	180.0	222.3
1997-A	C/128	234.0	0.96	118.65	18.71	13	1	110	86	7.7	259.0	221.2
1997-A	E/157	142.0	1.93	198.43	18.71	11	-2	38	58	2.6	158.0	145.8
1997-A	E/156	135.0	1.93	151.75	18.71	17	-1	70	80	4.2	135.0	131.9
1997-A	E/90	142.0	1.93	74.01	18.71	27	-1	70	50	3.6	158.0	172.1
1997-A	R/162B	1295.0	1.42	188.15	28.48	31	-1	70	30	1.7	1505.0	1472.7
1997-A	R/162LA	262.0	1.35	126.23	28.48	11	-1	56	30	1.6	273.0	290.0
1997-A	R/162G	440.0	1.93	196.53	28.48	33	-1	90	70	2.3	489.0	476.4
1997-A	R/25A	397.0	1.35	116.88	28.48	17	-1	85	109	4.4	446.0	379.8
1997-A	R/25D	600.0	1.35	181.30	28.48	25	-1	50	109	4.5	619.0	627.0
1997-A	R/254	385.0	1.35	117.92	28.48	12	1	46	36	1.4	417.0	409.5
1997-A	S/69	365.0	0.29	96.78	16.36	15	-1	73	71	5.1	417.0	375.3
1997-A	J/146	517.0	0.29	95.09	16.36	13	-1	62	78	4.8	540.0	549.6
1997-A	L/179	532.0	0.35	63.56	14.03	11	0	86	35	3.0	597.0	551.0
1997-A	L/87	918.0	0.35	80.67	14.03	47	0	82	45	3.4	782.0	887.3
1997-A	L/127	454.0	0.35	45.09	14.03	30	0	60	30	3.4	689.0	449.5
1997-A	L/43	639.0	0.35	61.24	14.03	36	-1	79	69	3.9	684.0	656.1
1997-A	L/176	532.0	0.35	149.77	14.03	14	-1	110	50	3.4	597.0	566.9
1997-A	P/144	193.0	0.47	108.24	12.16	5	-3	80	30	2.8	203.0	205.7
1997-A	P/138	203.0	0.47	3.60	12.16	17	-4	67	33	3.6	193.0	237.9
1997-A	P/124	358.0	0.47	166.19	12.16	24	-3	48	42	3.1	371.0	355.7
1997-A	P/15	655.0	0.23	130.46	12.16	29	-3	18	34	3.6	658.0	652.6
1997-B	D/67	55.0	42.35	27.66	16.15	20	-2	79	80	2.4	56.0	71.9
1997-B	E/61	145.0	49.18	30.42	16.15	23	-1	43	40	1.3	42.0	144.6
1997-B	A/185	100.0	49.18	150.89	16.15	14	-2	80	95	3.6	77.0	81.0
1997-B	C/127	100.0	49.18	34.87	16.15	32	0	75	115	5.6	70.0	96.1
1997-B	D/74	65.0	49.18	142.48	16.15	0	-2	81	50	2.0	56.0	64.3
1997-B	D/68	122.0	49.18	172.71	16.15	9	-2	72	58	2.6	112.0	105.3
1997-B	D/60	129.0	49.18	55.78	16.15	38	-2	45	43	3.3	129.0	138.5
1997-B	E/4	100.0	49.18	76.91	16.15	37	-1	34	124	4.7	84.0	91.7
1997-B	E/154	180.0	49.18	186.47	24.39	22	-2	92	50	1.7	178.0	186.1
1997-B	C/128	259.0	24.59	92.84	16.15	13	1	110	86	7.7	217.0	239.1
1997-B	E/157	158.0	49.18	191.25	16.15	11	-2	38	58	2.6	136.0	133.8
1997-B	E/90	158.0	49.18	94.07	16.15	27	-1	70	50	3.6	105.0	148.8
1997-B	R/162B	504.0	32.84	21.17	24.39	31	-1	70	30	1.7	530.0	487.5
1997-B	C/76	420.0	24.59	0.00	16.15	54	0	38	90	6.5	420.0	418.4
1997-B	R/162L	312.0	39.96	178.43	24.39	27	-1	110	45	1.7	300.0	311.1
1997-B	R/162LA	273.0	39.96	131.76	24.39	11	-1	56	30	1.6	287.0	267.8
1997-B	R/162G	489.0	49.18	194.06	24.39	33	-1	90	70	2.3	441.0	491.6

Time phase	Well	Cl_o	R	Q	Qr	Ot	Wl	Dw	Th	Ds	Cl_f	Cl_{f-} predicted
1997-B	R/25A	446.0	39.96	154.96	24.39	17	-1	85	109	4.4	437.0	449.0
1997-B	R/25D	619.0	39.96	153.48	24.39	25	-1	50	109	4.5	546.0	639.4
1997-B	R/254	417.0	39.96	106.78	24.39	12	1	46	36	1.4	315.0	405.9
1997-B	R/265	129.5	39.96	0.00	24.39	2	1	39	40	1.0	56.0	146.2
1997-B	S/69	417.0	9.40	92.01	12.43	15	-1	73	71	5.1	336.0	417.8
1997-B	J/146	540.0	9.40	40.88	12.43	13	-1	62	78	4.8	506.0	555.6
1997-B	L/159	396.0	27.34	64.75	13.35	24	0	42	40	2.4	497.0	365.1
1997-B	L/87	782.0	13.67	79.61	13.35	47	0	82	45	3.4	756.0	735.0
1997-B	L/127	689.0	13.67	34.78	13.35	30	0	60	30	3.4	580.0	642.9
1997-B	L/43	684.0	13.67	60.97	13.35	36	-1	79	69	3.9	630.0	683.7
1997-B	L/176	597.0	13.67	108.47	13.35	14	-1	110	50	3.4	560.0	612.8
1997-B	L/41	986.0	9.76	32.55	13.35	41	0	54	60	5.1	889.0	954.0
1997-B	P/144	203.0	25.90	121.13	11.37	5	-3	80	30	2.8	168.0	185.4
1997-B	P/138	193.0	25.90	12.24	11.37	17	-4	67	33	3.6	168.0	195.5
1997-B	P/124	371.0	25.90	136.22	11.37	24	-3	48	42	3.1	359.0	335.2
1997-B	P/15	658.0	12.95	0.15	11.37	29	-3	18	34	3.6	490.0	597.6
1998-A	D/67	56.0	0.53	63.76	19.68	21	-2	79	80	2.4	56.0	77.7
1998-A	A/180	49.0	0.53	28.58	19.68	16	-2	82	90	3.1	56.0	62.9
1998-A	D/73	56.0	0.53	50.45	19.68	2	-2	79	53	2.1	63.0	85.9
1998-A	E/61	42.0	0.44	28.58	19.68	24	-1	43	40	1.3	135.0	103.8
1998-A	A/185	77.0	0.44	124.94	19.68	15	-2	80	95	3.6	85.0	71.3
1998-A	D/71	70.0	0.44	149.70	19.68	0	-2	50	43	2.7	78.0	91.7
1998-A	C/127	70.0	0.58	64.11	19.68	33	0	75	115	5.6	70.0	69.6
1998-A	D/74	56.0	0.44	162.24	19.68	1	-2	81	50	2.0	71.0	75.4
1998-A	D/70	70.0	0.44	168.94	19.68	2	-2	42	40	3.0	85.0	93.3
1998-A	D/69	78.0	0.44	175.51	19.68	5	-2	40	58	2.7	78.0	89.4
1998-A	E/6	56.0	0.44	7.52	19.68	36	-1	31	100	4.6	85.0	80.7
1998-A	E/142	77.0	0.44	53.47	19.68	0	-3	37	52	2.1	100.0	101.2
1998-A	D/68	112.0	0.44	172.64	19.68	10	-2	72	58	2.6	120.0	121.8
1998-A	D/60	129.0	0.44	54.81	19.68	39	-2	45	43	3.3	121.0	174.7
1998-A	E/4	84.0	0.44	121.02	19.68	38	-1	34	124	4.7	78.0	74.9
1998-A	E/154	178.0	0.44	157.06	30.95	23	-2	92	50	1.7	230.0	215.4
1998-A	C/128	217.0	0.29	138.27	19.68	14	1	110	86	7.7	235.0	205.5
1998-A	E/157	136.0	0.44	182.99	19.68	12	-2	38	58	2.6	156.0	144.1
1998-A	R/162B	530.0	0.23	31.23	30.95	32	-1	70	30	1.7	497.0	541.1
1998-A	C/76	420.0	0.29	46.01	19.68	55	0	38	90	6.5	470.0	442.2
1998-A	R/162L	300.0	0.27	206.95	30.95	28	-1	110	45	1.7	319.0	339.3
1998-A	R/162LA	287.0	0.27	206.95	30.95	12	-1	56	30	1.6	284.0	329.6
1998-A	R/162G	441.0	0.44	187.88	30.95	34	-1	90	70	2.3	461.0	474.2
1998-A	R/162HA	458.0	0.27	195.39	30.95	8	-1	85	69	2.4	483.0	491.1
1998-A	R/162H	546.0	0.27	149.87	30.95	25	-1	90	69	2.4	511.0	573.8
1998-A	R/25A	437.0	0.42	149.51	30.95	18	-1	85	109	4.4	426.0	429.9
1998-A	R/25B	532.0	0.42	192.39	30.95	48	-1	52	109	4.5	497.0	553.3
1998-A	R/113	42.0	0.27	52.17	30.95	33	1	32	40	0.8	206.0	101.4
1998-A	R/25D	546.0	0.42	129.32	30.95	26	-1	50	109	4.5	603.0	542.2
1998-A	R/254	315.0	0.27	97.52	30.95	13	1	46	36	1.4	390.0	338.0
1998-A	R/265	56.0	0.27	73.42	30.95	3	1	39	40	1.0	135.0	107.8
1998-A	R/74	798.0	0.21	25.21	30.95	6	0	45	100	5.0	774.0	765.7
1998-A	R/75	707.0	0.21	82.67	30.95	8	0	62	100	5.0	745.0	693.4

Time phase	Well	Cl_o	R	Q	Qr	Ot	Wl	Dw	Th	Ds	Cl_f	$Cl_{f\text{-}predicted}$
1998-A	S/69	336.0	0.35	92.18	18.76	16	-1	73	71	5.1	400.0	345.1
1998-A	J/146	506.0	0.35	111.06	18.76	14	-1	62	78	4.8	541.0	538.2
1998-A	L/179	315.0	0.08	57.53	19.20	12	0	86	35	3.0	369.0	337.9
1998-A	L/159A	189.0	0.15	57.82	19.20	0	0	62	30	2.5	248.0	215.2
1998-A	L/159	497.0	0.15	53.53	19.20	25	0	42	40	2.4	491.0	519.4
1998-A	L/87	756.0	0.08	64.32	19.20	48	0	82	45	3.4	782.0	758.1
1998-A	L/127	580.0	0.08	59.26	19.20	31	0	60	30	3.4	588.0	593.8
1998-A	L/43	630.0	0.08	69.84	19.20	37	-1	79	69	3.9	660.0	663.8
1998-A	L/176	560.0	0.08	138.78	19.20	15	-1	110	50	3.4	598.0	608.4
1998-A	L/41	889.0	0.05	35.93	19.20	42	0	54	60	5.1	923.0	901.9
1998-A	P/139	28.0	0.18	27.98	19.20	0	-1	30	30	0.8	50.0	86.5
1998-A	P/144	168.0	0.18	100.50	12.67	6	-3	80	30	2.8	177.0	186.3
1998-A	P/145	118.0	0.18	63.60	12.67	2	-4	75	40	4.0	248.0	143.6
1998-A	P/124	359.0	0.18	115.56	12.67	25	-3	48	42	3.1	348.0	360.0
1998-A	P/15	490.0	0.09	100.19	12.67	30	-3	18	34	3.6	617.0	480.2
1998-B	D/67	56.0	17.48	57.74	17.00	21	-2	79	80	2.4	42.0	76.3
1998-B	A/180	56.0	17.48	8.15	17.00	16	-2	82	90	3.1	49.0	71.8
1998-B	D/73	63.0	17.48	53.36	17.00	2	-2	79	53	2.1	63.0	85.2
1998-B	D/72	71.0	13.04	65.44	17.00	0	-2	46	41	2.9	77.0	97.7
1998-B	E/61	135.0	13.04	8.15	17.00	24	-1	43	40	1.3	182.0	172.1
1998-B	A/185	85.0	13.04	83.74	17.00	15	-2	80	95	3.6	84.0	79.5
1998-B	D/71	78.0	13.04	126.59	17.00	0	-2	50	43	2.7	74.0	93.2
1998-B	C/127	70.0	18.14	52.16	17.00	33	0	75	115	5.6	77.0	73.9
1998-B	D/74	71.0	13.04	150.84	17.00	1	-2	81	50	2.0	77.0	81.5
1998-B	D/70	85.0	13.04	170.89	17.00	2	-2	42	40	3.0	88.0	96.9
1998-B	D/69	78.0	13.04	171.86	17.00	5	-2	40	58	2.7	70.0	82.9
1998-B	E/6	85.0	13.04	5.21	17.00	36	-1	31	100	4.6	77.0	105.8
1998-B	E/142	100.0	13.04	49.38	17.00	0	-3	37	52	2.1	112.0	115.7
1998-B	D/68	120.0	13.04	159.30	17.00	10	-2	72	58	2.6	98.0	121.7
1998-B	D/60	121.0	13.04	44.67	17.00	39	-2	45	43	3.3	119.0	160.3
1998-B	E/4	78.0	13.04	109.49	17.00	38	-1	34	124	4.7	70.0	71.8
1998-B	E/154	230.0	13.04	178.48	27.27	23	-2	92	50	1.7	266.0	256.0
1998-B	C/128	235.0	9.07	99.71	17.00	14	1	110	86	7.7	217.0	221.8
1998-B	E/157	156.0	13.04	147.20	17.00	12	-2	38	58	2.6	161.0	155.5
1998-B	E/156	121.0	13.04	133.13	17.00	18	-1	70	80	4.2	140.0	118.2
1998-B	R/162B	497.0	16.31	0.00	27.27	32	-1	70	30	1.7	491.0	496.8
1998-B	C/76	470.0	9.07	4.56	17.00	55	0	38	90	6.5	448.0	479.9
1998-B	R/162L	319.0	18.19	152.31	27.27	28	-1	110	45	1.7	272.0	338.1
1998-B	R/162LA	284.0	18.19	77.75	27.27	12	-1	56	30	1.6	224.0	297.8
1998-B	R/162G	461.0	13.04	141.08	27.27	34	-1	90	70	2.3	435.0	485.5
1998-B	R/162HA	483.0	18.19	185.40	27.27	8	-1	85	69	2.4	462.0	512.0
1998-B	R/162H	511.0	18.19	163.99	27.27	25	-1	90	69	2.4	497.0	538.4
1998-B	R/112	707.0	18.19	52.47	27.27	33	1	36	30	0.6	482.0	711.8
1998-B	R/25A	426.0	12.64	51.36	27.27	18	-1	85	109	4.4	455.0	405.8
1998-B	R/25B	497.0	12.64	138.94	27.27	48	-1	52	109	4.5	490.0	517.2
1998-B	R/113	206.0	18.19	141.07	27.27	33	1	32	40	0.8	235.0	232.4
1998-B	R/25D	603.0	12.64	103.42	27.27	26	-1	50	109	4.5	628.0	613.4
1998-B	R/254	390.0	18.19	58.12	27.27	13	1	46	36	1.4	372.0	397.0
1998-B	R/265	135.0	18.19	108.41	27.27	3	1	39	40	1.0	140.0	164.2

Time phase	Well	Cl_o	R	Q	Qr	Ot	Wl	Dw	Th	Ds	Cl_f	$Cl_{f\text{-}predicted}$
1998-B	R/74	774.0	6.32	15.68	27.27	6	0	45	100	5.0	651.0	765.2
1998-B	S/69	400.0	4.77	77.88	16.53	16	-1	73	71	5.1	385.0	411.4
1998-B	J/146	541.0	4.77	106.32	16.53	14	-1	62	78	4.8	539.0	576.5
1998-B	L/179	369.0	3.66	44.19	16.13	12	0	86	35	3.0	336.0	384.8
1998-B	L/159A	248.0	7.33	53.31	16.13	0	0	62	30	2.5	280.0	262.8
1998-B	L/159	491.0	7.33	47.51	16.13	25	0	42	40	2.4	483.0	494.8
1998-B	L/87	782.0	3.66	85.88	16.13	48	0	82	45	3.4	782.0	769.4
1998-B	L/127	588.0	3.66	65.40	16.13	31	0	60	30	3.4	595.0	583.7
1998-B	L/43	660.0	3.66	60.81	16.13	37	-1	79	69	3.9	611.0	681.8
1998-B	L/176	598.0	3.66	108.77	16.13	15	-1	110	50	3.4	630.0	636.9
1998-B	L/41	923.0	2.62	35.93	16.13	42	0	54	60	5.1	945.0	918.3
1998-B	P/139	50.0	5.89	5.86	16.13	0	-1	30	30	0.8	35.0	106.4
1998-B	P/144	177.0	5.89	161.97	11.83	6	-3	80	30	2.8	217.0	177.7
1998-B	P/145	248.0	5.89	98.27	11.83	2	-4	75	40	4.0	210.0	247.7
1998-B	P/124	348.0	5.89	117.74	11.83	25	-3	48	42	3.1	368.0	338.4
1999-A	A/180	49.0	2.22	5.56	20.65	17	-2	82	90	3.1	63.0	67.0
1999-A	D/73	63.0	2.22	102.76	20.65	3	-2	79	53	2.1	63.0	86.4
1999-A	A/185	84.0	1.47	132.13	20.65	16	-2	80	95	3.6	77.0	80.0
1999-A	D/71	74.0	1.47	102.79	20.65	1	-2	50	43	2.7	66.0	101.0
1999-A	C/127	77.0	1.52	60.84	20.65	34	0	75	115	5.6	84.0	77.3
1999-A	D/74	77.0	1.47	196.21	20.65	2	-2	81	50	2.0	77.0	93.4
1999-A	D/69	70.0	1.47	171.94	20.65	6	-2	40	58	2.7	70.0	86.1
1999-A	E/6	77.0	1.47	10.87	20.65	37	-1	31	100	4.6	70.0	97.2
1999-A	E/142	112.0	1.47	16.35	20.65	1	-3	37	52	2.1	105.0	135.9
1999-A	D/68	98.0	1.47	141.80	20.65	11	-2	72	58	2.6	119.0	114.1
1999-A	D/60	119.0	1.47	75.13	20.65	40	-2	45	43	3.3	105.0	164.0
1999-A	C/79	427.0	0.76	4.57	20.65	29	0	64	90	6.4	463.7	436.8
1999-A	E/4	70.0	1.47	94.34	20.65	39	-1	34	124	4.7	70.0	67.8
1999-A	E/154	266.0	1.47	167.99	31.67	24	-2	92	50	1.7	190.0	300.3
1999-A	C/128	217.0	0.76	120.01	20.65	15	1	110	86	7.7	224.0	207.9
1999-A	E/157	161.0	1.47	176.99	20.65	13	-2	38	58	2.6	159.0	170.1
1999-A	E/90	147.0	1.47	195.00	20.65	29	-1	70	50	3.6	154.0	169.6
1999-A	R/162B	491.0	0.88	30.34	31.67	33	-1	70	30	1.7	490.0	501.4
1999-A	R/162L	272.0	1.03	193.38	31.67	29	-1	110	45	1.7	300.0	311.1
1999-A	R/162LA	224.0	1.03	125.66	31.67	13	-1	56	30	1.6	315.0	259.2
1999-A	R/162G	435.0	1.47	172.83	31.67	35	-1	90	70	2.3	469.0	464.4
1999-A	R/162H	497.0	1.03	175.57	31.67	26	-1	90	69	2.4	469.0	527.6
1999-A	Q/68	147.0	1.35	42.97	20.65	0	-1	73	104	5.0	161.0	106.0
1999-A	R/25A	455.0	1.35	134.87	31.67	19	-1	85	109	4.4	435.0	444.5
1999-A	R/25B	490.0	1.35	56.86	31.67	49	-1	52	109	4.5	491.0	478.4
1999-A	R/25D	628.0	1.35	90.20	31.67	27	-1	50	109	4.5	574.0	612.2
1999-A	R/254	372.0	1.03	61.23	31.67	14	1	46	36	1.4	385.0	387.0
1999-A	S/69	385.0	0.38	67.25	19.06	17	-1	73	71	5.1	385.0	399.2
1999-A	J/146	539.0	0.38	94.09	19.06	15	-1	62	78	4.8	525.0	574.3
1999-A	L/179	336.0	0.82	51.77	18.16	13	0	86	35	3.0	371.0	357.8
1999-A	L/159	483.0	1.63	49.32	18.16	26	0	42	40	2.4	504.0	500.4
1999-A	L/87	782.0	0.82	24.31	18.16	49	0	82	45	3.4	750.0	759.1
1999-A	L/43	611.0	0.82	60.43	18.16	38	-1	79	69	3.9	630.0	638.5
1999-A	L/41	945.0	0.58	64.47	18.16	43	0	54	60	5.1	945.0	967.4

Time phase	Well	Cl_o	R	Q	Qr	Ot	Wl	Dw	Th	Ds	Cl_f	$Cl_{f\text{-}predicted}$
1999-A	P/139	35.0	1.28	6.46	18.16	1	-1	30	30	0.8	49.0	97.2
1999-A	P/144	217.0	1.28	164.83	14.08	7	-3	80	30	2.8	210.0	222.6
1999-A	P/145	210.0	1.28	98.45	14.08	3	-4	75	40	4.0	246.0	219.5
1999-A	P/138	91.0	1.28	59.48	14.08	19	-4	67	33	3.6	99.4	135.9
1999-A	P/124	368.0	1.28	151.81	14.08	26	-3	48	42	3.1	397.0	372.5
1999-B	A/180	63.0	48.11	5.56	18.32	17	-2	82	90	3.1	70.0	75.5
1999-B	D/73	63.0	48.11	68.30	18.32	3	-2	79	53	2.1	63.0	74.3
1999-B	A/185	77.0	43.86	116.28	18.32	16	-2	80	95	3.6	91.3	75.3
1999-B	D/71	66.0	43.86	193.38	18.32	1	-2	50	43	2.7	77.0	72.8
1999-B	C/127	84.0	46.16	43.95	18.32	34	0	75	115	5.6	77.0	89.7
1999-B	D/74	77.0	43.86	191.38	18.32	2	-2	81	50	2.0	77.0	79.1
1999-B	D/69	70.0	43.86	173.28	18.32	6	-2	40	58	2.7	98.0	74.0
1999-B	E/6	70.0	43.86	6.22	18.32	37	-1	31	100	4.6	84.0	91.5
1999-B	D/68	119.0	43.86	178.39	18.32	11	-2	72	58	2.6	91.0	112.5
1999-B	C/79	463.7	23.08	38.59	18.32	29	0	64	90	6.4	483.0	467.5
1999-B	E/4	70.0	43.86	85.69	18.32	39	-1	34	124	4.7	77.0	75.8
1999-B	E/154	190.0	43.86	175.27	27.75	24	-2	92	50	1.7	322.0	210.3
1999-B	C/128	224.0	23.08	72.59	18.32	15	1	110	86	7.7	231.0	211.8
1999-B	E/157	159.0	43.86	174.57	18.32	13	-2	38	58	2.6	182.0	145.7
1999-B	E/90	154.0	43.86	183.02	18.32	29	-1	70	50	3.6	168.0	150.2
1999-B	R/162L	300.0	40.81	191.77	27.75	29	-1	110	45	1.7	413.0	309.7
1999-B	R/162G	469.0	43.86	164.50	27.75	35	-1	90	70	2.3	490.0	475.2
1999-B	R/162H	469.0	40.81	105.87	27.75	26	-1	90	69	2.4	476.0	470.0
1999-B	Q/68	161.0	40.32	169.74	18.32	0	-1	73	104	5.0	161.0	129.1
1999-B	R/25A	435.0	40.32	135.42	27.75	19	-1	85	109	4.4	483.0	440.2
1999-B	R/25B	491.0	40.32	79.80	27.75	49	-1	52	109	4.5	539.0	494.1
1999-B	R/25D	574.0	40.32	147.94	27.75	27	-1	50	109	4.5	672.0	582.8
1999-B	R/254	385.0	40.81	90.55	27.75	14	1	46	36	1.4	413.0	378.4
1999-B	S/69	385.0	10.69	81.13	17.89	17	-1	73	71	5.1	406.0	391.7
1999-B	J/146	525.0	10.69	107.43	17.89	15	-1	62	78	4.8	574.0	552.5
1999-B	L/179	371.0	11.37	51.97	17.48	13	0	86	35	3.0	420.0	377.7
1999-B	L/159	504.0	22.74	54.34	17.48	26	0	42	40	2.4	490.0	492.1
1999-B	L/43	630.0	11.37	66.25	17.48	38	-1	79	69	3.9	657.0	647.8
1999-B	L/41	945.0	8.12	61.48	17.48	43	0	54	60	5.1	952.0	956.0
1999-B	P/138	99.4	23.35	27.59	12.77	19	-4	67	33	3.6	85.7	130.0
1999-B	P/15	630.0	11.67	69.51	12.77	31	-3	18	34	3.6	428.0	595.6
2000-A	D/67	42.0	0.12	33.11	22.32	23	-2	79	80	2.4	35.3	72.6
2000-A	A/180	70.0	0.12	14.56	22.32	18	-2	82	90	3.1	77.0	82.1
2000-A	D/73	63.0	0.12	102.25	22.32	4	-2	79	53	2.1	56.0	89.5
2000-A	D/72	70.0	2.04	173.83	22.32	2	-2	46	41	2.9	63.0	98.1
2000-A	A/185	91.3	2.04	111.46	22.32	17	-2	80	95	3.6	91.0	90.9
2000-A	D/71	77.0	2.04	201.56	22.32	2	-2	50	43	2.7	70.0	102.1
2000-A	C/127	77.0	0.00	62.57	22.32	35	0	75	115	5.6	77.0	78.7
2000-A	D/74	77.0	2.04	155.89	22.32	3	-2	81	50	2.0	77.0	99.5
2000-A	D/70	91.0	2.04	158.07	22.32	4	-2	42	40	3.0	91.0	117.2
2000-A	D/69	98.0	2.04	168.69	22.32	7	-2	40	58	2.7	91.0	114.2
2000-A	E/6	84.0	2.04	84.86	22.32	38	-1	31	100	4.6	91.0	99.8
2000-A	D/68	91.0	2.04	188.65	22.32	12	-2	72	58	2.6	126.0	110.9
2000-A	C/79	483.0	0.00	39.24	22.32	30	0	64	90	6.4	478.0	497.5

Time phase	**Well**	**Cl_o**	**R**	**Q**	**Qr**	**Ot**	**Wl**	**Dw**	**Th**	**Ds**	**Cl_f**	**Cl_{f-} predicted**
2000-A	E/4	77.0	2.04	78.89	22.32	40	-1	34	124	4.7	77.0	76.7
2000-A	E/154	322.0	2.04	174.27	32.24	25	-2	92	50	1.7	371.2	356.1
2000-A	C/128	231.0	0.00	101.76	22.32	16	1	110	86	7.7	245.0	224.0
2000-A	E/157	182.0	2.04	167.82	22.32	14	-2	38	58	2.6	175.0	194.3
2000-A	E/156	140.0	2.04	159.69	22.32	20	-1	70	80	4.2	161.0	146.3
2000-A	E/90	168.0	2.04	175.07	22.32	30	-1	70	50	3.6	175.0	192.9
2000-A	C/76	525.0	0.00	19.54	22.32	57	0	38	90	6.5	532.0	544.3
2000-A	R/162G	490.0	2.04	152.97	32.24	36	-1	90	70	2.3	514.0	514.8
2000-A	R/162H	476.0	0.14	134.68	32.24	27	-1	90	69	2.4	490.0	495.4
2000-A	Q/68	161.0	2.02	209.71	22.32	1	-1	73	104	5.0	171.4	133.3
2000-A	R/112	392.0	0.14	60.01	32.24	35	1	36	30	0.6	368.0	410.2
2000-A	R/25A	483.0	2.02	126.27	32.24	20	-1	85	109	4.4	465.0	470.4
2000-A	R/25B	539.0	2.02	183.94	32.24	50	-1	52	109	4.5	564.0	554.7
2000-A	R/113	259.0	0.14	76.55	32.24	35	1	32	40	0.8	280.0	285.0
2000-A	R/25D	672.0	2.02	155.85	32.24	28	-1	50	109	4.5	714.0	678.4
2000-A	R/254	413.0	0.14	116.30	32.24	15	1	46	36	1.4	392.0	436.6
2000-A	S/69	406.0	0.00	75.49	21.17	18	-1	73	71	5.1	428.4	422.2
2000-A	J/146	574.0	0.00	109.91	21.17	16	-1	62	78	4.8	567.0	616.3
2000-A	L/179	420.0	0.00	65.82	20.23	14	0	86	35	3.0	420.0	444.8
2000-A	L/159	490.0	0.00	57.96	20.23	27	0	42	40	2.4	469.0	513.4
2000-A	L/127	630.0	0.00	79.55	20.23	33	0	60	30	3.4	678.3	649.6
2000-A	L/43	657.0	0.00	66.25	20.23	39	-1	79	69	3.9	700.0	690.9
2000-A	L/41	952.0	0.00	76.32	20.23	44	0	54	60	5.1	1013.9	988.0
2000-A	P/138	85.7	0.00	50.10	14.85	20	-4	67	33	3.6	114.2	135.7
2000-A	P/15	428.0	0.00	90.29	14.85	32	-3	18	34	3.6	671.0	430.3
2000-B	D/67	35.3	55.46	30.00	19.63	23	-2	79	80	2.4	35.5	61.8
2000-B	A/180	77.0	55.46	43.37	19.63	18	-2	82	90	3.1	84.0	84.5
2000-B	D/73	56.0	55.46	73.93	19.63	4	-2	79	53	2.1	70.6	69.9
2000-B	D/72	63.0	60.96	166.51	19.63	2	-2	46	41	2.9	63.5	71.0
2000-B	A/185	91.0	60.96	112.72	19.63	17	-2	80	95	3.6	84.7	89.0
2000-B	D/71	70.0	60.96	184.56	19.63	2	-2	50	43	2.7	77.7	75.2
2000-B	C/127	77.0	56.00	42.50	19.63	35	0	75	115	5.6	77.7	87.7
2000-B	D/74	77.0	60.96	101.11	19.63	3	-2	81	50	2.0	76.5	80.9
2000-B	D/70	91.0	60.96	152.29	19.63	4	-2	42	40	3.0	98.8	90.8
2000-B	D/69	91.0	60.96	181.04	19.63	7	-2	40	58	2.7	98.8	89.0
2000-B	E/6	91.0	60.96	81.90	19.63	38	-1	31	100	4.6	98.8	100.6
2000-B	D/68	126.0	60.96	174.68	19.63	12	-2	72	58	2.6	127.1	116.2
2000-B	C/79	478.0	28.00	13.95	19.63	30	0	64	90	6.4	473.0	477.9
2000-B	E/4	77.0	60.96	32.85	19.63	40	-1	34	124	4.7	69.5	88.1
2000-B	E/154	371.2	60.96	140.29	28.22	25	-2	92	50	1.7	466.0	360.0
2000-B	C/128	245.0	28.00	82.65	19.63	16	1	110	86	7.7	247.1	233.4
2000-B	E/157	175.0	60.96	139.73	19.63	14	-2	38	58	2.6	176.5	155.8
2000-B	E/156	161.0	60.96	118.70	19.63	20	-1	70	80	4.2	153.0	146.4
2000-B	E/90	175.0	60.96	130.65	19.63	30	-1	70	50	3.6	139.1	163.3
2000-B	C/76	532.0	28.00	10.89	19.63	57	0	38	90	6.5	578.9	533.0
2000-B	R/162G	514.0	60.96	154.18	28.22	36	-1	90	70	2.3	515.4	504.2
2000-B	R/162HA	490.0	56.46	93.99	28.22	10	-1	85	69	2.4	501.3	478.0
2000-B	R/162H	490.0	56.46	132.42	28.22	27	-1	90	69	2.4	508.3	482.5
2000-B	Q/68	171.4	60.21	199.26	19.63	1	-1	73	104	5.0	176.5	145.0

Time phase	Well	Cl_o	R	Q	Qr	Ot	Wl	Dw	Th	Ds	Cl_f	$Cl_{f\text{-predicted}}$
2000-B	R/25A	465.0	60.21	118.81	28.22	20	-1	85	109	4.4	472.9	460.6
2000-B	R/113	280.0	56.46	73.24	28.22	35	1	32	40	0.8	303.6	274.3
2000-B	R/25D	714.0	60.21	175.96	28.22	28	-1	50	109	4.5	706.0	708.7
2000-B	R/254	392.0	56.46	72.83	28.22	15	1	46	36	1.4	402.4	371.5
2000-B	S/69	428.4	22.65	53.77	19.25	18	-1	73	71	5.1	466.0	428.8
2000-B	J/146	567.0	22.65	103.08	19.25	16	-1	62	78	4.8	577.3	590.3
2000-B	L/159A	350.0	42.99	64.01	18.82	2	0	62	30	2.5	236.5	319.9
2000-B	L/159	469.0	42.99	52.80	18.82	27	0	42	40	2.4	486.9	438.2
2000-B	L/87	896.0	21.50	49.04	18.82	50	0	82	45	3.4	918.1	864.7
2000-B	L/127	678.3	21.50	71.44	18.82	33	0	60	30	3.4	667.7	666.7
2000-B	L/43	700.0	21.50	43.42	18.82	39	-1	79	69	3.9	695.5	707.4
2000-B	L/41	1013.9	15.35	70.86	18.82	44	0	54	60	5.1	987.6	1032.3
2000-B	P/144	242.7	34.30	128.28	13.71	8	-3	80	30	2.8	264.3	216.0
2000-B	P/145	257.0	34.30	0.00	13.71	4	-4	75	40	4.0	264.3	242.1
2000-B	P/15	671.0	17.15	48.39	13.71	32	-3	18	34	3.6	695.5	629.2
2001-A	D/67	35.5	0.58	48.20	23.99	24	-2	79	80	2.4	35.3	68.4
2001-A	A/180	84.0	0.58	69.11	23.99	19	-2	82	90	3.1	92.2	93.0
2001-A	D/73	70.6	0.58	103.72	23.99	5	-2	79	53	2.1	70.9	98.6
2001-A	D/72	63.5	2.14	174.81	23.99	3	-2	46	41	2.9	85.1	97.9
2001-A	E/61	1412.0	2.14	149.77	23.99	27	-1	43	40	1.3	1744.1	1576.6
2001-A	A/185	84.7	2.14	144.95	23.99	18	-2	80	95	3.6	106.4	91.5
2001-A	D/71	77.7	2.14	185.71	23.99	3	-2	50	43	2.7	92.2	108.3
2001-A	C/127	77.7	0.58	68.88	23.99	36	0	75	115	5.6	77.9	82.1
2001-A	D/74	76.5	2.14	166.44	23.99	4	-2	81	50	2.0	70.8	104.0
2001-A	D/70	98.8	2.14	151.15	23.99	5	-2	42	40	3.0	99.3	128.1
2001-A	D/69	98.8	2.14	170.48	23.99	8	-2	40	58	2.7	106.8	120.2
2001-A	E/6	98.8	2.14	86.92	23.99	39	-1	31	100	4.6	99.3	114.2
2001-A	D/68	127.1	2.14	177.29	23.99	13	-2	72	58	2.6	134.7	147.3
2001-A	C/79	473.0	0.29	33.80	23.99	31	0	64	90	6.4	489.2	482.5
2001-A	E/4	69.5	2.14	60.11	23.99	41	-1	34	124	4.7	77.9	73.7
2001-A	E/154	466.0	2.14	149.18	32.81	26	-2	92	50	1.7	567.2	492.7
2001-A	C/128	247.1	0.29	107.64	23.99	17	1	110	86	7.7	248.2	242.9
2001-A	E/157	176.5	2.14	159.68	23.99	15	-2	38	58	2.6	170.2	193.1
2001-A	E/156	153.0	2.14	163.91	23.99	21	-1	70	80	4.2	148.8	163.1
2001-A	E/90	139.1	2.14	177.93	23.99	31	-1	70	50	3.6	177.2	170.2
2001-A	R/162L	499.1	0.37	184.03	32.81	31	-1	110	45	1.7	494.2	534.7
2001-A	R/162G	515.4	2.14	183.70	32.81	37	-1	90	70	2.3	526.8	545.6
2001-A	R/162HA	501.3	0.37	85.40	32.81	11	-1	85	69	2.4	512.6	500.0
2001-A	R/162H	508.3	0.37	139.84	32.81	28	-1	90	69	2.4	505.5	528.1
2001-A	R/25A	472.9	2.28	121.43	32.81	21	-1	85	109	4.4	482.1	458.7
2001-A	R/113	303.6	0.37	73.73	32.81	36	1	32	40	0.8	313.2	325.7
2001-A	R/25D	706.0	2.28	193.60	32.81	29	-1	50	109	4.5	716.1	722.9
2001-A	R/25C	932.0	2.28	48.99	32.81	44	-1	45	109	4.5	942.9	911.1
2001-A	R/254	402.4	0.37	107.34	32.81	16	1	46	36	1.4	412.9	424.1
2001-A	L/159A	236.5	1.31	71.20	22.29	3	0	62	30	2.5	325.6	258.9
2001-A	L/159	486.9	1.31	58.94	22.29	28	0	42	40	2.4	496.3	510.5
2001-A	L/87	918.1	0.65	64.78	22.29	51	0	82	45	3.4	948.4	924.6
2001-A	L/127	667.7	0.65	95.31	22.29	34	0	60	30	3.4	693.6	696.6
2001-A	L/43	695.5	0.65	70.12	22.29	40	-1	79	69	3.9	714.8	731.5

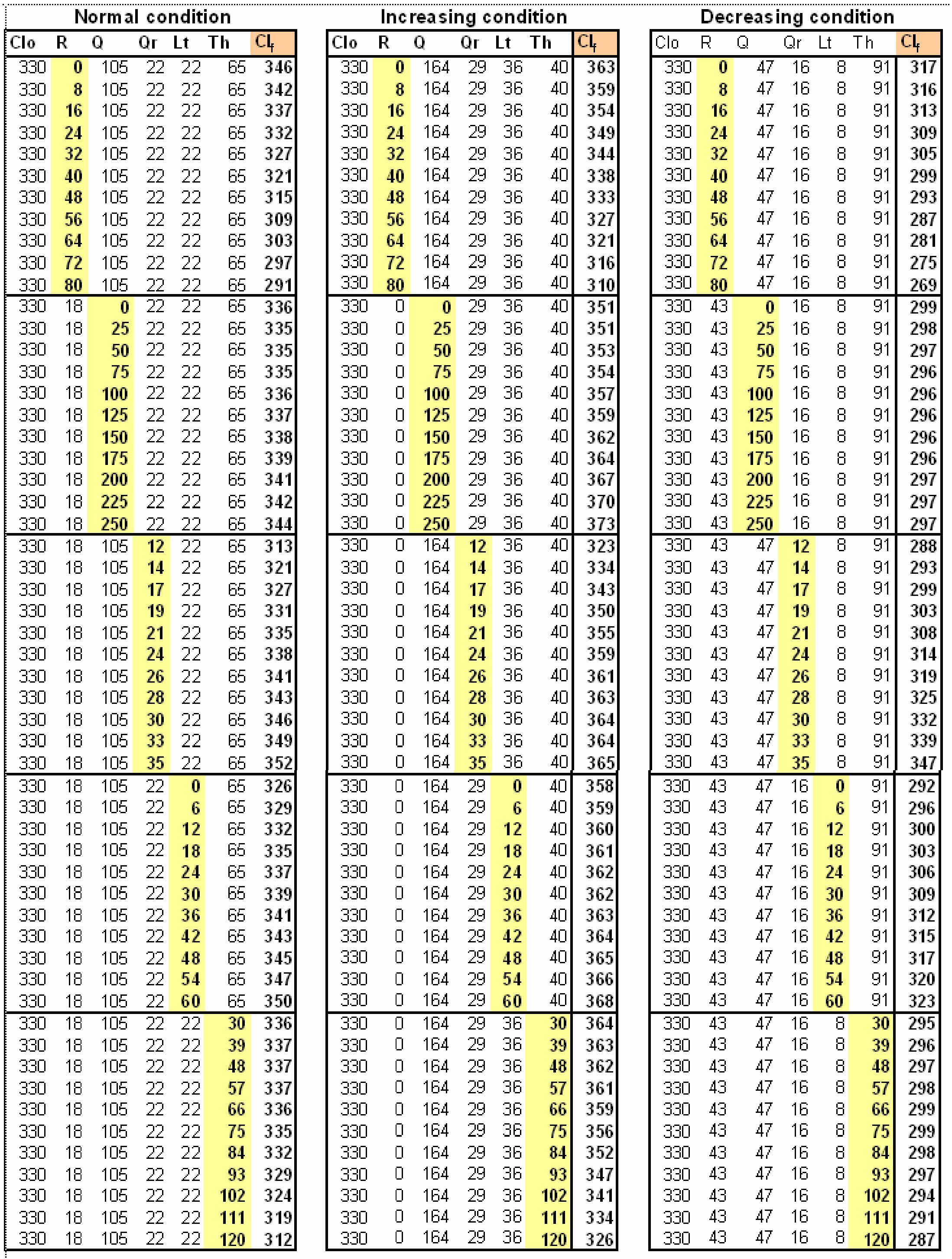
Time phase	**Well**	**Cl_o**	**R**	**Q**	**Qr**	**Ot**	**Wl**	**Dw**	**Th**	**Ds**	**Cl_f**	**$Cl_{f\text{-}predicted}$**
2001-A	L/176	744.2	0.65	139.84	22.29	18	-1	110	50	3.4	813.9	825.0
2001-A	L/41	987.6	0.47	78.70	22.29	45	0	54	60	5.1	990.9	1029.4
2001-A	P/144	264.3	1.63	126.24	15.61	9	-3	80	30	2.8	278.6	275.3
2001-A	P/145	264.3	1.63	0.00	15.61	5	-4	75	40	4.0	271.4	292.0
2001-A	P/124	424.3	1.63	176.74	15.61	28	-3	48	42	3.1	442.8	438.6
2001-A	P/15	695.5	0.82	86.36	15.61	33	-3	18	34	3.6	721.4	698.2
2001-B	D/67	35.3	62.13	31.39	20.95	24	-2	79	80	2.4	42.5	63.6
2001-B	A/180	92.2	62.13	45.14	20.95	19	-2	82	90	3.1	106.1	98.5
2001-B	D/73	70.9	62.13	84.23	20.95	5	-2	79	53	2.1	70.8	81.3
2001-B	D/72	85.1	63.84	166.99	20.95	3	-2	46	41	2.9	85.7	90.0
2001-B	A/185	106.4	63.84	131.04	20.95	18	-2	80	95	3.6	113.2	105.7
2001-B	D/71	92.2	63.84	139.67	20.95	3	-2	50	43	2.7	100.0	94.7
2001-B	C/127	77.9	62.29	60.65	20.95	36	0	75	115	5.6	92.0	91.5
2001-B	D/74	70.8	63.84	131.79	20.95	4	-2	81	50	2.0	92.0	79.8
2001-B	D/70	99.3	63.84	128.92	20.95	5	-2	42	40	3.0	107.1	100.3
2001-B	D/69	106.8	63.84	145.33	20.95	8	-2	40	58	2.7	114.3	105.3
2001-B	E/6	99.3	63.84	59.11	20.95	39	-1	31	100	4.6	106.1	111.5
2001-B	D/68	134.7	63.84	182.67	20.95	13	-2	72	58	2.6	142.8	127.2
2001-B	C/79	489.2	31.14	24.25	20.95	31	0	64	90	6.4	502.5	489.0
2001-B	E/4	77.9	63.84	37.04	20.95	41	-1	34	124	4.7	70.8	92.8
2001-B	C/128	248.2	31.14	91.95	20.95	17	1	110	86	7.7	261.8	239.0
2001-B	E/157	170.2	63.84	165.42	20.95	15	-2	38	58	2.6	178.6	155.6
2001-B	E/156	148.8	63.84	151.73	20.95	21	-1	70	80	4.2	184.6	140.3
2001-B	R/162L	494.2	61.79	139.80	28.70	31	-1	110	45	1.7	521.4	476.4
2001-B	R/162G	526.8	63.84	134.01	28.70	37	-1	90	70	2.3	542.0	512.6
2001-B	R/162HA	512.6	61.79	95.73	28.70	11	-1	85	69	2.4	485.7	497.0
2001-B	R/162H	505.5	61.79	125.31	28.70	28	-1	90	69	2.4	485.7	492.6
2001-B	R/25A	482.1	68.22	117.71	28.70	21	-1	85	109	4.4	500.0	472.6
2001-B	R/25B	545.9	68.22	144.20	28.70	51	-1	52	109	4.5	500.0	530.9
2001-B	R/113	313.2	61.79	69.27	28.70	36	1	32	40	0.8	328.6	300.5
2001-B	R/25D	716.1	68.22	188.49	28.70	29	-1	50	109	4.5	750.0	698.4
2001-B	R/25C	942.9	68.22	1.34	28.70	44	-1	45	109	4.5	928.6	896.4
2001-B	R/254	412.9	61.79	82.19	28.70	16	1	46	36	1.4	407.0	388.9
2001-B	L/159A	325.6	34.97	73.38	20.17	3	0	62	30	2.5	324.2	308.8
2001-B	L/159	496.3	34.97	52.10	20.17	28	0	42	40	2.4	486.0	477.9
2001-B	L/127	693.6	17.48	87.59	20.17	34	0	60	30	3.4	690.7	697.1
2001-B	L/43	714.8	17.48	58.35	20.17	40	-1	79	69	3.9	718.9	733.0
2001-B	L/176	813.9	17.48	144.75	20.17	18	-1	110	50	3.4	838.7	895.8
2001-B	L/41	990.9	12.49	75.61	20.17	45	0	54	60	5.1	972.0	1016.6
2001-B	P/144	278.6	27.27	116.66	14.65	9	-3	80	30	2.8	204.4	258.6
2001-B	P/145	271.4	27.27	0.00	14.65	5	-4	75	40	4.0	281.9	265.1
2001-B	P/138	128.6	27.27	56.09	14.65	21	-4	67	33	3.6	204.4	145.0
2001-B	P/124	442.8	27.27	181.50	14.65	28	-3	48	42	3.1	444.0	426.1
2002-A	D/67	42.5	1.11	43.03	25.65	25	-2	79	80	2.4	35.5	75.6
2002-A	A/180	106.1	1.11	63.72	25.65	20	-2	82	90	3.1	99.5	113.6
2002-A	D/73	70.8	1.11	125.74	25.65	6	-2	79	53	2.1	64.0	102.7
2002-A	D/72	85.7	2.62	172.84	25.65	4	-2	46	41	2.9	78.2	121.2
2002-A	A/185	113.2	2.62	175.84	25.65	19	-2	80	95	3.6	106.0	123.5
2002-A	D/71	100.0	2.62	200.22	25.65	4	-2	50	43	2.7	71.0	133.4

Time phase	**Well**	**Cl_o**	**R**	**Q**	**Qr**	**Ot**	**Wl**	**Dw**	**Th**	**Ds**	**Cl_f**	**$Cl_{f\text{-predicted}}$**
2002-A	D/74	92.0	2.62	175.08	25.65	5	-2	81	50	2.0	86.5	122.7
2002-A	D/70	107.1	2.62	138.90	25.65	6	-2	42	40	3.0	78.1	139.3
2002-A	D/69	114.3	2.62	170.52	25.65	9	-2	40	58	2.7	85.2	139.1
2002-A	E/6	106.1	2.62	80.81	25.65	40	-1	31	100	4.6	85.0	122.5
2002-A	D/68	142.8	2.62	191.37	25.65	14	-2	72	58	2.6	106.0	167.4
2002-A	C/79	502.5	0.85	52.38	25.65	32	0	64	90	6.4	476.0	513.0
2002-A	E/4	70.8	2.62	41.71	25.65	42	-1	34	124	4.7	77.9	76.9
2002-A	E/154	235.7	2.62	131.76	33.38	27	-2	92	50	1.7	177.6	268.8
2002-A	C/128	261.8	0.85	98.56	25.65	18	1	110	86	7.7	248.0	259.1
2002-A	E/157	178.6	2.62	163.73	25.65	16	-2	38	58	2.6	127.9	199.6
2002-A	E/156	184.6	2.62	196.08	25.65	22	-1	70	80	4.2	156.0	200.3
2002-A	C/76	608.6	0.85	22.41	25.65	59	0	38	90	6.5	593.0	622.2
2002-A	R/162L	521.4	2.18	166.89	33.38	32	-1	110	45	1.7	518.0	551.3
2002-A	R/162LA	664.3	2.18	154.76	33.38	16	-1	56	30	1.6	710.0	701.8
2002-A	R/162G	542.0	2.62	165.67	33.38	38	-1	90	70	2.3	782.0	566.7
2002-A	R/162HA	485.7	2.18	178.59	33.38	12	-1	85	69	2.4	490.0	513.7
2002-A	R/162H	485.7	2.18	130.73	33.38	29	-1	90	69	2.4	490.0	502.3
2002-A	Q/68	150.0	2.47	231.34	25.65	3	-1	73	104	5.0	177.0	145.5
2002-A	R/25A	500.0	2.47	126.53	33.38	22	-1	85	109	4.4	483.0	487.0
2002-A	R/25B	500.0	2.47	155.76	33.38	52	-1	52	109	4.5	504.0	507.3
2002-A	R/25D	750.0	2.47	208.94	33.38	30	-1	50	109	4.5	710.0	769.8
2002-A	R/254	407.0	2.18	104.61	33.38	17	1	46	36	1.4	397.8	427.2
2002-A	R/265	221.4	2.18	53.12	33.38	7	1	39	40	1.0	199.0	244.4
2002-A	L/159A	324.2	1.40	76.99	24.36	4	0	62	30	2.5	325.9	345.2
2002-A	L/159	486.0	1.40	51.99	24.36	29	0	42	40	2.4	474.7	508.8
2002-A	L/127	690.7	0.70	88.53	24.36	35	0	60	30	3.4	708.5	720.6
2002-A	L/43	718.9	0.70	73.17	24.36	41	-1	79	69	3.9	722.7	754.3
2002-A	L/176	838.7	0.70	134.28	24.36	19	-1	110	50	3.4	850.2	931.4
2002-A	P/144	204.4	0.93	142.40	16.38	10	-3	80	30	2.8	248.0	218.4
2002-A	P/145	281.9	0.93	0.00	16.38	6	-4	75	40	4.0	283.4	309.9
2002-A	P/138	204.4	0.93	62.91	16.38	22	-4	67	33	3.6	141.7	231.9
2002-A	P/124	444.0	0.93	187.38	16.38	29	-3	48	42	3.1	708.5	464.8
2002-B	D/67	35.5	83.07	30.90	22.27	25	-2	79	80	2.4	50.0	63.1
2002-B	A/180	99.5	83.07	57.37	22.27	20	-2	82	90	3.1	99.5	103.9
2002-B	D/73	64.0	83.07	95.90	22.27	6	-2	79	53	2.1	71.6	75.2
2002-B	D/72	78.2	78.19	172.42	22.27	4	-2	46	41	2.9	78.4	86.5
2002-B	A/185	106.0	78.19	141.74	22.27	19	-2	80	95	3.6	107.4	109.0
2002-B	D/71	71.0	78.19	214.88	22.27	4	-2	50	43	2.7	85.5	82.8
2002-B	D/70	78.1	78.19	126.16	22.27	6	-2	42	40	3.0	99.8	85.7
2002-B	D/69	85.2	78.19	159.84	22.27	9	-2	40	58	2.7	99.8	91.7
2002-B	E/6	85.0	78.19	61.63	22.27	40	-1	31	100	4.6	107.8	102.1
2002-B	D/68	106.0	78.19	188.31	22.27	14	-2	72	58	2.6	142.6	107.0
2002-B	C/79	476.0	46.05	17.52	22.27	32	0	64	90	6.4	479.7	465.0
2002-B	E/4	77.9	78.19	44.45	22.27	42	-1	34	124	4.7	87.7	96.3
2002-B	C/128	248.0	46.05	90.40	22.27	18	1	110	86	7.7	222.0	237.7
2002-B	E/157	127.9	78.19	149.75	22.27	16	-2	38	58	2.6	189.3	122.7
2002-B	E/156	156.0	78.19	179.72	22.27	22	-1	70	80	4.2	164.7	146.2
2002-B	E/90	191.0	78.19	166.67	22.27	32	-1	70	50	3.6	200.5	175.7
2002-B	C/76	593.0	46.05	16.68	22.27	59	0	38	90	6.5	615.8	585.9

Time phase	Well	Cl_o	R	Q	Qr	Ot	Wl	Dw	Th	Ds	Cl_f	$Cl_{f\text{-predicted}}$
2002-B	R/162L	518.0	71.65	153.33	29.17	32	-1	110	45	1.7	620.0	491.9
2002-B	R/162LA	710.0	71.65	149.24	29.17	16	-1	56	30	1.6	710.0	695.4
2002-B	R/162G	782.0	78.19	178.15	29.17	38	-1	90	70	2.3	542.0	755.0
2002-B	R/162HA	490.0	71.65	151.82	29.17	12	-1	85	69	2.4	520.5	474.9
2002-B	R/162H	490.0	71.65	131.97	29.17	29	-1	90	69	2.4	477.7	469.7
2002-B	Q/68	177.0	73.77	199.14	22.27	3	-1	73	104	5.0	178.3	164.8
2002-B	R/25A	483.0	73.77	120.69	29.17	22	-1	85	109	4.4	484.8	470.5
2002-B	R/25B	504.0	73.77	129.37	29.17	52	-1	52	109	4.5	513.4	486.5
2002-B	R/25D	710.0	73.77	182.87	29.17	30	-1	50	109	4.5	727.0	682.5
2002-B	R/254	397.8	71.65	73.56	29.17	17	1	46	36	1.4	363.6	367.4
2002-B	R/265	199.0	71.65	47.26	29.17	7	1	39	40	1.0	199.6	201.5
2002-B	L/159A	325.9	33.27	95.22	21.51	4	0	62	30	2.5	315.0	314.0
2002-B	L/159	474.7	33.27	65.87	21.51	29	0	42	40	2.4	472.6	462.7
2002-B	L/87	949.4	16.64	69.03	21.51	52	0	82	45	3.4	954.0	942.9
2002-B	L/127	708.5	16.64	80.62	21.51	35	0	60	30	3.4	694.0	715.0
2002-B	L/43	722.7	16.64	70.59	21.51	41	-1	79	69	3.9	744.6	746.9
2002-B	L/176	850.2	16.64	119.28	21.51	19	-1	110	50	3.4	826.0	926.4
2002-B	P/144	248.0	23.43	103.73	15.59	10	-3	80	30	2.8	293.6	238.5
2002-B	P/145	283.4	23.43	0.00	15.59	6	-4	75	40	4.0	286.4	282.3
2002-B	P/138	141.7	23.43	59.61	15.59	22	-4	67	33	3.6	171.8	159.0
2003-A	D/67	50.0	1.40	48.39	27.32	26	-2	79	80	2.4	42.6	83.2
2003-A	A/180	99.5	1.40	83.71	27.32	21	-2	82	90	3.1	113.6	113.1
2003-A	D/73	71.6	1.40	128.11	27.32	7	-2	79	53	2.1	63.9	108.3
2003-A	A/185	107.4	1.41	246.55	27.32	20	-2	80	95	3.6	120.7	132.9
2003-A	D/70	99.8	1.41	150.54	27.32	7	-2	42	40	3.0	106.5	138.1
2003-A	D/69	99.8	1.41	188.73	27.32	10	-2	40	58	2.7	113.6	134.0
2003-A	E/6	107.8	1.41	16.47	27.32	41	-1	31	100	4.6	114.1	121.8
2003-A	D/68	142.6	1.41	208.75	27.32	15	-2	72	58	2.6	142.0	174.5
2003-A	C/79	479.7	0.70	6.77	27.32	33	0	64	90	6.4	475.7	476.0
2003-A	E/4	87.7	1.41	58.15	27.32	43	-1	34	124	4.7	92.3	91.9
2003-A	E/154	841.0	1.41	154.59	33.94	28	-2	92	50	1.7	1036.6	883.7
2003-A	C/128	222.0	0.70	103.49	27.32	19	1	110	86	7.7	255.6	223.1
2003-A	E/157	189.3	1.41	176.15	27.32	17	-2	38	58	2.6	184.6	215.1
2003-A	E/156	164.7	1.41	199.56	27.32	23	-1	70	80	4.2	156.2	187.3
2003-A	E/90	200.5	1.41	179.28	27.32	33	-1	70	50	3.6	184.6	233.5
2003-A	C/76	615.8	0.70	17.86	27.32	60	0	38	90	6.5	624.8	624.3
2003-A	R/162L	620.0	1.07	186.49	33.94	33	-1	110	45	1.7	624.8	654.9
2003-A	R/162LA	710.0	1.07	141.22	33.94	17	-1	56	30	1.6	823.6	744.6
2003-A	R/162G	542.0	1.41	214.81	33.94	39	-1	90	70	2.3	553.8	575.6
2003-A	R/162HA	520.5	1.07	205.72	33.94	13	-1	85	69	2.4	511.2	556.3
2003-A	R/162H	477.7	1.07	157.41	33.94	30	-1	90	69	2.4	560.9	500.1
2003-A	Q/68	178.3	1.63	254.94	27.32	4	-1	73	104	5.0	170.4	184.9
2003-A	R/25A	484.8	1.63	130.61	33.94	23	-1	85	109	4.4	497.0	472.2
2003-A	R/25B	513.4	1.63	198.60	33.94	53	-1	52	109	4.5	539.6	526.6
2003-A	R/113	335.1	1.07	90.93	33.94	38	1	32	40	0.8	326.6	356.8
2003-A	R/25D	727.0	1.63	213.99	33.94	31	-1	50	109	4.5	745.5	742.9
2003-A	R/254	363.6	1.07	75.57	33.94	18	1	46	36	1.4	369.2	380.2
2003-A	R/265	199.6	1.07	55.68	33.94	8	1	39	40	1.0	198.6	226.6
2003-A	L/159A	315.0	1.21	118.75	26.43	5	0	62	30	2.5	308.0	338.6

Time phase	**Well**	**Cl_o**	**R**	**Q**	**Qr**	**Ot**	**Wl**	**Dw**	**Th**	**Ds**	**Cl_f**	**$Cl_{f\text{-}predicted}$**
2003-A	L/159	472.6	1.21	76.88	26.43	30	0	42	40	2.4	472.6	496.7
2003-A	L/87	954.0	0.61	84.09	26.43	53	0	82	45	3.4	938.0	977.4
2003-A	L/127	694.0	0.61	79.99	26.43	36	0	60	30	3.4	737.5	721.1
2003-A	L/43	744.6	0.61	116.65	26.43	42	-1	79	69	3.9	744.6	791.5
2003-A	L/176	826.0	0.61	140.09	26.43	20	-1	110	50	3.4	895.0	910.3
2003-A	L/41	974.0	0.43	82.56	26.43	47	0	54	60	5.1	966.6	1014.6
2003-A	P/144	293.6	2.33	119.51	17.15	11	-3	80	30	2.8	293.6	307.0
2003-A	P/145	286.4	2.33	0.00	17.15	7	-4	75	40	4.0	286.4	312.8
2003-A	P/138	171.8	2.33	72.31	17.15	23	-4	67	33	3.6	186.2	201.9
2003-A	P/124	458.2	2.33	198.03	17.15	30	-3	48	42	3.1	458.2	483.0

ANNEX 7 : ANN model Results of hypothetical cases studied the effect of input variables on chloride concentration



Normal condition

Clo	R	Q	Qr	Lt	Th	Cl_f
330	**0**	105	22	22	65	**346**
330	**8**	105	22	22	65	**342**
330	**16**	105	22	22	65	**337**
330	**24**	105	22	22	65	**332**
330	**32**	105	22	22	65	**327**
330	**40**	105	22	22	65	**321**
330	**48**	105	22	22	65	**315**
330	**56**	105	22	22	65	**309**
330	**64**	105	22	22	65	**303**
330	**72**	105	22	22	65	**297**
330	**80**	105	22	22	65	**291**
330	18	**0**	22	22	65	**336**
330	18	**25**	22	22	65	**335**
330	18	**50**	22	22	65	**335**
330	18	**75**	22	22	65	**335**
330	18	**100**	22	22	65	**336**
330	18	**125**	22	22	65	**337**
330	18	**150**	22	22	65	**338**
330	18	**175**	22	22	65	**339**
330	18	**200**	22	22	65	**341**
330	18	**225**	22	22	65	**342**
330	18	**250**	22	22	65	**344**
330	18	105	**12**	22	65	**313**
330	18	105	**14**	22	65	**321**
330	18	105	**17**	22	65	**327**
330	18	105	**19**	22	65	**331**
330	18	105	**21**	22	65	**335**
330	18	105	**24**	22	65	**338**
330	18	105	**26**	22	65	**341**
330	18	105	**28**	22	65	**343**
330	18	105	**30**	22	65	**346**
330	18	105	**33**	22	65	**349**
330	18	105	**35**	22	65	**352**
330	18	105	22	**0**	65	**326**
330	18	105	22	**6**	65	**329**
330	18	105	22	**12**	65	**332**
330	18	105	22	**18**	65	**335**
330	18	105	22	**24**	65	**337**
330	18	105	22	**30**	65	**339**
330	18	105	22	**36**	65	**341**
330	18	105	22	**42**	65	**343**
330	18	105	22	**48**	65	**345**
330	18	105	22	**54**	65	**347**
330	18	105	22	**60**	65	**350**
330	18	105	22	22	**30**	**336**
330	18	105	22	22	**39**	**337**
330	18	105	22	22	**48**	**337**
330	18	105	22	22	**57**	**337**
330	18	105	22	22	**66**	**336**
330	18	105	22	22	**75**	**335**
330	18	105	22	22	**84**	**332**
330	18	105	22	22	**93**	**329**
330	18	105	22	22	**102**	**324**
330	18	105	22	22	**111**	**319**
330	18	105	22	22	**120**	**312**

Increasing condition

Clo	R	Q	Qr	Lt	Th	Cl_f
330	**0**	164	29	36	40	**363**
330	**8**	164	29	36	40	**359**
330	**16**	164	29	36	40	**354**
330	**24**	164	29	36	40	**349**
330	**32**	164	29	36	40	**344**
330	**40**	164	29	36	40	**338**
330	**48**	164	29	36	40	**333**
330	**56**	164	29	36	40	**327**
330	**64**	164	29	36	40	**321**
330	**72**	164	29	36	40	**316**
330	**80**	164	29	36	40	**310**
330	0	**0**	29	36	40	**351**
330	0	**25**	29	36	40	**351**
330	0	**50**	29	36	40	**353**
330	0	**75**	29	36	40	**354**
330	0	**100**	29	36	40	**357**
330	0	**125**	29	36	40	**359**
330	0	**150**	29	36	40	**362**
330	0	**175**	29	36	40	**364**
330	0	**200**	29	36	40	**367**
330	0	**225**	29	36	40	**370**
330	0	**250**	29	36	40	**373**
330	0	164	**12**	36	40	**323**
330	0	164	**14**	36	40	**334**
330	0	164	**17**	36	40	**343**
330	0	164	**19**	36	40	**350**
330	0	164	**21**	36	40	**355**
330	0	164	**24**	36	40	**359**
330	0	164	**26**	36	40	**361**
330	0	164	**28**	36	40	**363**
330	0	164	**30**	36	40	**364**
330	0	164	**33**	36	40	**364**
330	0	164	**35**	36	40	**365**
330	0	164	29	**0**	40	**358**
330	0	164	29	**6**	40	**359**
330	0	164	29	**12**	40	**360**
330	0	164	29	**18**	40	**361**
330	0	164	29	**24**	40	**362**
330	0	164	29	**30**	40	**362**
330	0	164	29	**36**	40	**363**
330	0	164	29	**42**	40	**364**
330	0	164	29	**48**	40	**365**
330	0	164	29	**54**	40	**366**
330	0	164	29	**60**	40	**368**
330	0	164	29	36	**30**	**364**
330	0	164	29	36	**39**	**363**
330	0	164	29	36	**48**	**362**
330	0	164	29	36	**57**	**361**
330	0	164	29	36	**66**	**359**
330	0	164	29	36	**75**	**356**
330	0	164	29	36	**84**	**352**
330	0	164	29	36	**93**	**347**
330	0	164	29	36	**102**	**341**
330	0	164	29	36	**111**	**334**
330	0	164	29	36	**120**	**326**

Decreasing condition

Clo	R	Q	Qr	Lt	Th	Cl_f
330	**0**	47	16	8	91	**317**
330	**8**	47	16	8	91	**316**
330	**16**	47	16	8	91	**313**
330	**24**	47	16	8	91	**309**
330	**32**	47	16	8	91	**305**
330	**40**	47	16	8	91	**299**
330	**48**	47	16	8	91	**293**
330	**56**	47	16	8	91	**287**
330	**64**	47	16	8	91	**281**
330	**72**	47	16	8	91	**275**
330	**80**	47	16	8	91	**269**
330	43	**0**	16	8	91	**299**
330	43	**25**	16	8	91	**298**
330	43	**50**	16	8	91	**297**
330	43	**75**	16	8	91	**296**
330	43	**100**	16	8	91	**296**
330	43	**125**	16	8	91	**296**
330	43	**150**	16	8	91	**296**
330	43	**175**	16	8	91	**296**
330	43	**200**	16	8	91	**297**
330	43	**225**	16	8	91	**297**
330	43	**250**	16	8	91	**297**
330	43	47	**12**	8	91	**288**
330	43	47	**14**	8	91	**293**
330	43	47	**17**	8	91	**299**
330	43	47	**19**	8	91	**303**
330	43	47	**21**	8	91	**308**
330	43	47	**24**	8	91	**314**
330	43	47	**26**	8	91	**319**
330	43	47	**28**	8	91	**325**
330	43	47	**30**	8	91	**332**
330	43	47	**33**	8	91	**339**
330	43	47	**35**	8	91	**347**
330	43	47	16	**0**	91	**292**
330	43	47	16	**6**	91	**296**
330	43	47	16	**12**	91	**300**
330	43	47	16	**18**	91	**303**
330	43	47	16	**24**	91	**306**
330	43	47	16	**30**	91	**309**
330	43	47	16	**36**	91	**312**
330	43	47	16	**42**	91	**315**
330	43	47	16	**48**	91	**317**
330	43	47	16	**54**	91	**320**
330	43	47	16	**60**	91	**323**
330	43	47	16	8	**30**	**295**
330	43	47	16	8	**39**	**296**
330	43	47	16	8	**48**	**297**
330	43	47	16	8	**57**	**298**
330	43	47	16	8	**66**	**299**
330	43	47	16	8	**75**	**299**
330	43	47	16	8	**84**	**298**
330	43	47	16	8	**93**	**297**
330	43	47	16	8	**102**	**294**
330	43	47	16	8	**111**	**291**
330	43	47	16	8	**120**	**287**

ANNEX 8 : ANN model scenarios results

Ag No	Oct. 2007 Predicted	Scenario 1			Scenario2		Scenario 3		
		2010	2020	2030	2010	2020	After one year	2010	2020
D/67	101	92	212	331	50	50	50	50	50
A/180	187	187	235	284	89	50	50	50	50
D/73	127	93	167	241	50	50	50	50	50
D/72	149	154	404	654	50	50	50	50	50
A/185	181	211	411	612	50	50	50	50	50
D/71	159	193	525	857	50	50	50	50	50
D/74	224	286	674	1062	78	50	50	50	50
D/70	175	207	493	778	50	50	50	50	50
D/69	168	217	534	851	50	50	50	50	50
E/6	146	152	251	350	92	50	50	50	50
D/68	186	279	706	1134	67	50	50	50	50
E/4	124	107	151	196	50	50	50	50	50
E/154	2770	2898	3334	3770	2717	2549	2584	2217	935
C/128	258	296	446	596	226	143	136	50	50
E/157	250	321	731	1141	118	50	50	50	50
E/156	223	261	562	863	98	50	50	50	50
E/90	267	327	680	1032	153	50	50	50	50
C/76	690	759	925	1090	774	986	541	203	50
R/162LA	2049	2133	2564	2995	1940	1727	1826	1469	220
R/162G	703	822	1282	1742	666	604	504	144	50
R/162HA	568	715	1225	1734	495	270	425	151	50
R/162H	504	615	988	1362	476	388	338	50	50
Q/68	245	258	399	541	50	50	84	50	50
R/112	2350	2385	2488	2590	2294	2093	2131	1686	126
R/25A	486	560	737	914	389	50	370	95	50
R/25B	519	608	872	1136	541	583	369	51	50
R/25D	720	829	1151	1473	654	391	590	307	50
R/25C	1007	1063	1231	1399	1001	961	860	553	50
R/254	410	473	721	969	348	182	224	50	50
R/74	782	789	813	838	675	319	676	465	50
R/75	844	879	918	956	773	458	761	548	50
S/69	506	558	697	836	565	726	404	179	50
J/146	687	760	950	1139	727	809	598	389	50
L/159A	567	586	699	811	564	604	422	163	50
L/159	590	647	844	1041	578	543	407	50	50
L/87	908	1008	1380	1752	911	959	689	273	50
L/127	683	788	1152	1516	688	720	487	103	50
L/43	791	865	1125	1386	849	1057	630	318	50
L/176	570	706	1162	1617	608	733	439	179	50
L/41	1038	1129	1449	1769	1098	1313	860	515	50
P/139	249	268	406	545	268	409	102	50	50
P/145	440	477	681	884	373	228	295	54	50
P/138	486	529	738	947	344	50	298	50	50
P/124	524	565	785	1006	340	50	324	50	50
P/15	776	870	1182	1495	643	199	594	229	50