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Evaluation of Groundwater Potentiality and Exploitation in Barind Area and Its Impact on Environment

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Evaluation of Groundwater Potentiality and Exploitation in Barind Area and Its Impact on Environment

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IN
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November 2014

Dedicated To

My Father Md. Yasin Ali

And

My Mother Monoara Begum

DECLARATION

I do hereby declare that the thesis entitled **"Evaluation of Groundwater Potentiality and Exploitation in Barind Area and Its Impact on Environment"** is the result of my original research work and submitted to the Institute of Environmental Science at the University of Rajshahi, Rajshahi, Bangladesh for the degree of Doctor of Philosophy in Environmental Science.

I further declare that this thesis has not been submitted in part or full previously for the award of any other degree or diploma in any institution and to the best of my knowledge and belief, the research contains no material previously published or written by another person, except where due reference has been made in the text of the thesis.

(Md. Rashidul Hasan)

Certificate

This is to certify that Mr. Md. Rashidul Hasan is the sole author of the desertification entitled **'Evaluation of Groundwater Potentiality and Exploitation in Barind Area and Its Impact on Environment'.** This desertification or part thereof has not been the basis for the award of any degree, diploma or associated with any other similar title.

We are forwarding this desertification to be examined for the degree of Doctor of Philosophy in the Institute of Environmental Science (IES) at the University of Rajshahi, Rajshahi, Bangladesh. The data presented in the thesis are genuine and original. Mr. Rashidul Hasan has fulfilled all the requirements according to the rules of the University for submission of a desertification for the Ph. D degree and made distinct contribution to the environmental science.

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ABSTRACT

The study aimed to understand overexploitation, potentiality of groundwater for irrigation in Barind area and its probable impact on environmental. The study area was Chapai Nawabganj district in Barind area located in North-western part of Bangladesh. The study area consisted of five Upazilas in the district, namely Nawabganj, Shibganj, Nachole, Gomastapur and Bholahat.

The study has considered secondary data collected from different organizations and five boring log samples were collected from five Upazilas of Chapai Nawabganj district in Barind area. A total of 50 representatives deep tubewells (DTWs) water samples were collected from 5 selected locations of each Upazila during the month of March (pre-monsoon) and October (post-monsoon), 2014.

The experimental data were statistically analyzed using various software and the results were discussed to interpret the geochemical characteristics, water type, and water quality. The study results illustrate that the highest groundwater depletion was about 29 m found at Nawabganj Upazila in 2010 and the lowest was about 5 m at Shibganj in 2003. A 10-year rainfall data of the district showed that the maximum annual rainfall recorded was 1804 mm in 2007. Since then, rainfall was gradually decreasing for consecutive three years, but it was again increased 439 mm in 2011 from 1015 mm recorded in the previous year. The highest annual rainfall received in the area was 1793 mm in 2007 and the lowest was 1025 mm in 2010 in the district. The average rainfall received in Chapai Nawabganj district was 1372 mm during 2002-2011.

The estimated run-off and infiltration results of Chapai Nawabganj district in Barind area illustrate that decreasing trends in run-off and infiltration were observed for consecutive three years since 2007, but they were increased in 2011 in all Upazilas due to higher rainfall received. The analysis results show a good relation among rainfall, infiltration and run-off indicating that the higher amount was the rainfall, the higher amounts was the estimated runoff and infiltration.

A good trend of water table fluctuations of Chapai Nawabganj district was found during 2002 to 2011. The minimum groundwater level was recorded in 2004 and maximum was in 2011. The study results reveale that a good relation between rainfall

and water table fluctuations was observed where the groundwater table was recharged through the rainfall. The overall yearly water table declining trend indicate that the unsustainable withdrawal of groundwater for irrigation purposes played a vital role in groundwater table depletion in the study area. Moreover, groundwater level fluctuation depended on the extraction and recharge of the area.

Specific yield of the five Upazilas were determined and the values were found around 10 (%) which indicate good permeability of the areas, except Bholahat Upazila, where the value was 8.4 (%) indicating low permeability. The results illustrate that Nachole Upazila has a large storage volume, i.e., 49,305 Hec-m, but the other Upazilas have a storage capacity between 8000 to 18000 Hec-m. The storage capacity of the five Upazilas was followed the order: Nachole>Nawabganj>Shibganj>Gomastapur> Bholahat.

The highest number of DTWs was installed at Nachole Upazila in the district and the extracted amount was 8848 Hec-m and the amount for the district was 26822 Hec-m . The study results indicate that the over withdrawal of groundwater for irrigation has threaten sustainable water resource management.

The analysis results of the hydro-chemical composition of the DTWs water in Chapai Nawabganj district show that the groundwater of the study area was neutral to slightly alkaline pH and fresh category. Ca^{2+} was the dominant ionic species among the cations of the DTWs water samples, with an average of 50.37 mg/L (range 35.24-69.9 mg/L). The catonic order of the groundwater was: Ca^{2+}> Mg^{2+}> Na^{+}> K^{+}> Fe^{3+}> As(total). Among the anions, HCO_3^- was the dominant species with an average of 245.301 mg/L (range 60-510 mg/L). The major anions of the DTWs water were followed the order of HCO_3^-> Cl^-> SO_4^{2-}.

The Piper tri-linear diagram relating to HCO_3^-, SO_4^{2-} and Cl^- showed the most of the groundwater samples contain a high amount of HCO_3^- and the cation diagram showed the majority of groundwater samples contained higher amount of Ca^{2+}+ Mg^{2+} than Na^++K^+. The diagram showed that HCO_3^- and Ca^{2+} were the dominant ions in groundwater samples. Therefore, most of the analyzed DTWs water samples fall in the field of Ca^{2+}-HCO_3^- type in the quadrilateral diagram during the pre and post-monsoon.

As the Mg^{2+} concentration in water samples was lower compared to the Ca^{2+} concentration, thus the results suggest that the water type of this area was considered to be Ca^{2+}- HCO_3^-.

The analysis results suggest that the concentration of TH, HCO_3, Ca, Na, K, Mg, and Fe, ions in water were the cause of weathering of aquifer materials. So, groundwater of Chapai Nawabganj district in the Barind area shows a wide range of characteristics in terms of physical, chemical and microbial parameters during two seasons. The study observed that the quality of groundwater was very much suitable for irrigation and domestic purposes.

The study results illustrate the overexploitation of groundwater in Nachole Upazila has led to highest depletion (10 m) of water table in 10 years during study period. The scenario of water level depletion of the Upazila forcast the drought and water scarcity in the area will prevail if the unplanned groundwater extraction is continued in the long run. Despite a slow depletion of groundwater level in other Upazilas during the study period, a holistic approach in water resource management is very much needed for sustainable environment. The study results identified the groundwater extraction of Chapai Nawabganj district for irrigation as a critical environmental concerned. The study observe that the below average rainfall has another cause of groundwater depletion and thus further aggravated the situation in the study area. The key impediments to potentiality of groundwater have been identified as over exploitation of groundwater use in *Boro* rice cultivation in the Barind area. Fortunately, arsenic was not detected in any DTW water samples collected in the study despite the overdraft of groundwater in some parts of the study area.

The groundwater management for sustainable irrigation and crop production in the region is imperative. A well planned water resource management would be taken to achieve sustainable use of groundwater for irrigation aiming to achieve food security as well as ecological friendly environment.

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NOTATIONS

BADC	-	Bangladesh Agricultural Development Corporation
BMDA	-	Barind Multipurpose Development Authority
BMD	-	Bangladesh Meteorological Department
DTW	-	Deep Tubewells Water
EC	-	Electrical Conductivity
FC	-	Faecal Coliform
IWM	-	Institute of Water Modeling
J.L. No.	-	Jail Number
K	-	Permeability
Max	-	Maximum
MDG	-	Millennium Development Goals
Min	-	Minimum/Minute
P.L No.	-	Plot Number
PWD	-	Public Work Department
TDS	-	Total Dissolved Solid
TH	-	Total Hardness
UNDP	-	United Nation Development Programmed
WHO	-	World Health Organization

Chapter One

Introduction

INTRODUCTION

1.1 Introduction

Groundwater is a vital source of water through the world and Bangladesh. About 30% of the earth fresh water stores in underground aquifer (The Encyclopedia of Earth, website). It is the purest form of water and as its stores in underground for long periods and it can be available at a small capital cost and its value to mankind is unlimited. It is also flows over long distances through the aquifers and it is available to a very large number of people at their firms. The infiltrated water after meeting the soil moisture deficiency percolates deeply and becomes groundwater. The groundwater is free from pollution and is very useful for domestic use in small towns and isolated farms. In arid regions, ground water is often the only reliable source of water for irrigation. It could be wisely managed and protected against undue exploitation and contamination by pollutants or salt water. The potentiality of groundwater attracted the attention of agricultural engineers, civil engineers, geologists, geophysicists and scientists from various disciplines (Reddi, 1986).

Groundwater is basically a dynamic resource that may be expressed as the quantity of water measured by the difference between optimum and minimum water table within the aquifer, which is principally recharged from monsoon rainwater for the rest of the year. Exploitation or over withdrawal of groundwater resources imposes stress on groundwater regime distorting the aquifer recharge-withdrawal equilibrium and as a result, a continuous decline in water table may occur causing much adverse surface and subsurface environmental effect (Garg, 1976). Groundwater recharge is influenced not only by climate variability but also human intervention including, unsustainable withdrawal and groundwater abstraction. Groundwater-fed irrigation is conducted to cultivate high-yielding rice during the dry season in South Asia, where India and Bangladesh represent the world second and fourth biggest rice-producing nations respectably (Scott and Sharma, 2009) In Bangladesh, total annual (2004-2005) irrigation water use was estimated to be 246 km^3 of which 18 km^3 comes from groundwater (Siebert *et al*., 2010) via a range of pumping technologies. Recent studies in India and Bangladesh reported that a groundwater level (0.1- 0.5 m/year) was declining indicating reduction in aquifer storage for unsustainable groundwater abstraction for both irrigation and urban water supplies (Hasan *et al.,* 2013; Shamsudduha *et al.,* 2011; BMDA, 2006). In India, Punjab and Haryana are experiencing very rapid decline in water tables. This can threaten future food security in the country (Tribune News service, 2006). Water demand is increasing rapidly due to population growth and socioeconomic development in recent time, needed to take a holistic approach in this sector.

Bangladesh is the land of rivers, a number of rivers crossed over it. Agriculture in Bangladesh depends on irrigation during the dry eight months starting from November ending in June. Groundwater is the major water source for domestic and irrigation purposes. But the surface water is not enough to meet irrigation water demand in dry season. In general, the term groundwater or subsurface water refers to the water that occurs below the surface of the earth.

Concerning environmental issues, the biggest challenge is to maintain the quantity and improve the quality of natural resources and therefore to ensure a sustainable development of society. Sustainable development is a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development and institutional change are all in harmony and enhance both current and future potential of human needs and aspirations. This concept of sustainable development is relatively easier to define from the point of view of an economist.

1.2 Groundwater distribution in Bangladesh

Groundwater is a vital source of water supply in Bangladesh. Bangladesh is almost entirely underlain by water bearing formations at depths varying from zero to 12 meter below the ground surface. Most of the area of Bangladesh possesses deltaic formation of alluvial deposits. The land elevation is about 61 meter in the Northern plains and 15 meter in the middle plains and a few meters above mean sea level at the coastal plains. Having all these topographical and hydrological conditions, the soil strata in Bangladesh contains water more or less everywhere (Banglapedia, 2006) below water-table. But all strata do not contain sufficient water that can be pumped or may not give water for a long time. Three main rivers-the Padma, the Jamuna and the Meghna with their network of tributaries pass through the deltaic region of Bangladesh filling the lands with alluvial deposits and other unconsolidated material such as sand and gravel which the river carry with them draining the Himalayan ranges. The thickness of these stratified alluviums in the entire area exceeds 30 meter. The continuous layers although containing occasional lenses of clay occur at depth varying from 15 m to 90 m. Gravel is frequently marked with fine to medium sand. Coarse sand is found rarely and is thin layers. Within the stratified aquifer occurrence of medium sand is the maximum (BMDA, 2006).

While some groundwater reservoirs are being replenished year after year by infiltration from precipitation, rivers, canals and so on, other are being replenished to much lesser degree or not at all. Extraction of water from this later reservoirs results in the continued depletion of groundwater level. Many parts of Bangladesh are facing water supply problem due to the over exploration of groundwater. The planning of a water supply system requires knowledge of the extents of storage, the rate of discharge from and recharge to the underground reservoirs.

Rainfall is one of the major causes of groundwater level fluctuation but natural discharge and pumping effects have also effects on water level fluctuation. Rainfall is not an accurate indicator of groundwater recharge because of surface and subsurface losses as well as travel time of vertical perception.

1.3 Groundwater for irrigation use

A report showed the irrigation is responsible for more than 65% of all fresh water withdrawals and one quarter of world's irrigated land is supplied by groundwater and 75% of these lands are located in Asia. Before 1970, irrigation water in Bangladesh was mainly dependent on surface water and monsoon rainfall. But last two decades, about 79.1% of agriculture lands are supplied water for *Boro* rice from groundwater (Rahman and Mahbub, 2012).

Groundwater recharging in Bangladesh is mainly occur by monsoon rainfall and flooding. Due to high elevation of Barind, it is located in flood free zone. So, only source of groundwater recharging in this area is rainfall, but lowest amount of rainfall occur in northwestern part of Bangladesh and it is also a very severely drought prone area. Moreover, thick sticky clay surface of Barind tract act as aquitard which impede groundwater recharging and increase surface runoff. As a result, groundwater level in this part is successively falling by years with increasing withdrawal of water for irrigation.

Agriculture is by far the biggest user of water, accounting for more than 70 per cent of water withdrawals worldwide and more than 90 per cent water withdrawals in several low income developing countries. The largest increase in irrigated area during the coming decades is expected in India and China. A study in eight Asian countries revealed that of the additional 117 million tons of rice produced between 1965 and 1988, 34 million tons can be directly attributed to irrigation. Trends in water consumption indicate that demand for water for household and irrigation uses in developing countries could double as a proportion of total water demand in the next 25 years (Swaminathan, 2000).

Recharge from rainfall may be zero for arid or semi arid region but shallow water tables show definite response to rainfall. In unsaturated zone above a water table, moisture content is less than that of specific retention, that water table will not respond to recharge from rainfall until the deficiency has been satisfied. Groundwater table fluctuation in Bangladesh occurs at the beginning off monsoon season and gores down after monsoon season is river. A heavy rainfall during the month of August or September has hardly any influence on groundwater level while a similar rainfall in the month of July causes a sharp rise. At the end of August the groundwater table rises to the land surface (Hasan *et. al.*, 2013).

1.4 Evapotranspiration

In areas where the ground water level is very near to the surface, evaporation plays a dominant role in reducing the ground water level. Laboratory experiments have shown that if ground water level is in the range of one foot below the surface the highest rate of evaporation occurs and the ground water level reduces to 3 to 4 feet, after that certain limit the effect of evaporation does not occur literally.

Hot windy days produce more draw down that cold cloudy day as in the later case effect of evaporation in negligible. Transpiration discharge does not occur also where the ground water level is below the root zone of plants

The rainfall that percolates below the ground surface passes through the voids of the rocks, and joins the water table. These voids are generally interconnected permitting the movement of groundwater. But in some rocks, they may be isolated, and thus, preventing the movement of water between the interstices. It is evident that the mode of occurrence of groundwater depends largely upon the type of formation and the geology of the area.

The sub-surface occurrence of groundwater can be divided into two main regions,

(i) The zone of aeration, and

(ii) The zone of saturation.

The zone of aeration extents from the land surface to the level at which all of the pores in the earth material are not completely filled with water. It may be sub-divided into three belts, soil water zone, the capillary fringe zone and the intermediate zone.

In the zone of saturation all the openings are fully filled with water under hydrostatic pressure, hence the porosity is a direct measure of the water contain per unit volume. The water in the zone of saturation is generally known as groundwater. Not all of this water may be removed from the ground by pumping from a well, as molecular and surface tension forces will hold a portion of the water in place.

The word ‘Aquifer’ can be traced to its Latin origin. Aqui- is a combining form of aqua, meaning water and fer- comes from fere, to ear. Hence, an aquifer, literally, is a water bearer. The amount of water to be soaked by the earth depends upon the nature of rock or sediments. On the basis of the relation the rocks or sediments bear to the percolation of water. For the purpose of groundwater, the rock or sediment that can hold, transmit and yield water is called Aquifer and the accumulation of groundwater in a particular region will depend upon the presence of aquifers.

There are mainly two types of aquifer based on the permeability of the covering layers.

(i) Unconfined aquifer, and

(ii) Confined aquifer

An unconfined aquifer is one in which the water table serves as the upper surface of the saturation. It is also known the free parasitic or non-artesian aquifer. The groundwater level is free to rise or fall. The level of water table is the place where groundwater pressure is equal to the atmospheric pressure. Unconfined aquifers are commonly found in alluvium valleys, coastal plains, dunes and glacial deposits. The confined aquifer do not have free water table and are also known as artesian or pressure aquifers. The pressure conditions in a confined aquifer is characterized by the piezometric surface, which is the surface obtained by connecting equilibrium water levels in tubes or piezometers, penetrating the confined aquifer. A particular aquifer at one place may be a confined aquifer while at another place it may behave as an unconfined aquifer where the water level falls below the base of the overlying confining layer. The amount of groundwater which can be obtained in any area depends on the character of the underlying aquifer, its extent and the frequency of discharge. The yield of the water saturated formation is rob ably the most important single item of ultimate interest. Practically, in most cases the yield will determine whether or not the water saturation zone will be treated as a source of groundwater. One of the individual factors that affect the yield is the natural characteristics of the water bearing formation.

Storage function is the properties which control the entrance of water into water bearing formation, their capacity to hold, transmit and deliver of water, and confinement and concentration of percolation to the direction of maximum movement, soil materials contain void space. The space is described quantitatively by a property known as porosity an index of how much water could be stored within the aquifer in the groundwater reservoir. It is defined as the ratio of the volume of the voids between the grains to the total volume of the material. The size, arrangement and shape of grains and the degree of assortment are some of the factors controlling the porosity of granular material.

Specific yield is the water from unit volume of aquifer by pumping or drainage. It depends upon grain size, shape and distribution of pores and composition of the formation. Storage coefficient (S) of an aquifer is the volume of water discharge from a vertical column of aquifer standing on a unit area ($1m^2$) as water level (piezometric level in confined aquifer) falls by a unit depth ($1m^2$). For unconfined aquifers (water table condition) the storage co-efficient is the same as specific yield. The storage coefficient for confined aquifers ranges from 0.00005 to 0.005 and water table aquifers 0.05 to 0.03. Under artesian conditions, when the piezometric surface is lowered by pumping water is released from storage by the compression of the water bearing material (aquifer) and by expansion of the water itself. Thus, the co-efficient of storage is function of the elasticity of water and the aquifer skeleton.

The property of the water bearing formation which is related to its conduit function is called the permeability. Permeability (K) is a measure of the capacity of the porous media to transmit water under pressure. The co-efficient of transmissibility (T) is the discharge through unit width of aquifer for the fully saturated depth under a unit hydraulic gradient and is usually expressed as lpd/m or m^2/sec. It is the product of field permeability (K) and saturated thickness of the aquifer (b); T=Kb and has the dimension L^2/T. In order to study the movement of groundwater effectively and accurately, an intimate knowledge of geologic factor is necessary. Thus, the lithology, structural sequence, thickness and lateral extents and hydro-geological parameters must be known. The lateral gradation of particles is of great significant with respect to the movement of groundwater. Depending upon the hydraulic gradient and permeability, water may move in various directions. Both the lateral and vertical extends of aquifer must be accurately known for determining the rate to movement of groundwater.

1.5 Effect of Groundwater level Fluctuation

Any phenomenon, which produces pressure change within an aquifer, results into the change of ground water level. These changes in ground water level can be a result of changes in storage, amount of discharge and recharge, variation of stream stages and evaporation. External loads such as tides, trains, atmospheric pressure and earthquake are born in part by the ground water of confined aquifers. Hence they affect peizometric levels. The general consideration is that due to any reason if the aquifer pressure rises above the atmospheric pressure an up leveling in ground water level results and vice- versa.

1.6 Seasonal variation

These results from influence such as recharge from rainfall and irrigation and discharge by pumping which follow well defined seasonal cycles. Highest levels occur about

April and lowest about September marking the beginning and end of the irrigation seasons.

A few reports on groundwater level fluctuation, over withdrawal and its impact on environmet in the Barind tract so far have been published Therefore, a detailed research works considering rainfall impact on groundwater fluctuation and soil characteristics for recharge capacity in the region would have to be needed to get better understanding of aquifer status and to make sustainable water resource management.

This research program has considered rainfall, water level fluctuation data, drilling log data and water quality parameters of five Upazilas in Chapai Nawabganj district under the Barind tract in view of maintaining sustainable irrigation water supply to achieve food security as well as water resource management.

The Barind tract is nearly level over most of the extent, but is hilly and dissent by narrow valleys in the west. Major soils are mixed yellowish brown and grayish loam to clay loam. The total cultivated area being 1.44 million acres, out of which 34% is loamy, 10% sandy, 49% clayey, and 7% others. The monsoon season lasts from May/June until September and shows the typical monsoon characteristic of heavy rain and high humidity. The dry season from November to February is sunny and relatively cool, with only occasional scattered. Barind Tract made up of Pleistocene Alluvium also known as older Alluvium and floored by reddish brown sticky Pleistocene sediment (Shamsudduha *et al.*, 2011; UNDP, 1982; BADC, 2010).

The study has depended mostly on secondary data collected from different organizations. Groundwater samples were collected from the study area and analyzed for some major parameters. The study was based on groundwater monitoring well of Barind Multipurpose Development Authority 2002-2011 (BMDA). Rainfall data was collected from Bangladesh Meteorological Department (BMD). Litho logy of the study area was also studied from borehole logs collected from BMDA.

1.7 Water Quality

Geochemistry is the science that uses the tools and principles of chemistry to explain the mechanisms behind major geological systems such as the Earth’s crust and its oceans (Albarede, 2003). More specifically, it is the study of the absolute and relative abundances of chemical elements in the rocks, minerals, ores, soils, water and atmosphere of the earth and the distribution and movement of these elements from one place to another as a result of their chemical and physical changes (Konard, 1967). Of them changes, chemical studies provide insights into the mechanisms of ancient sedimentary rocks and the fluids contained in them. Today, important work in geochemistry involves the study of geochemical cycles in the atmosphere, marine and estuarine waters, and the earth's crust. There are many studies in relation to the effects of massive amounts of pollutants on the environment. Geochemistry of groundwater is an important factor for determining its use for various purposes such as domestic, irrigation and industrial uses. It depends on a number of factors, such as general geology, degree of chemical weathering of the various rock types, quality of recharge water and inputs from sources of other water-rock interaction (Domenico, 1972; Hem, 1989; Schuh *et al.,* 1997; Toth, 1984). This process that is responsible for altering the chemical composition of groundwater varies with respect with space and time. This process also helps to obtain an insight into the contributions of rock/soil-water interaction and anthropogenic influences on groundwater. So, interaction of groundwater with aquifer minerals through which it flows greatly controls the groundwater chemistry (Hussein, 2004).

Almost 71% of the earth's surface area is covered by water. Total water resources of the world are estimated at 1.36×108 million ha-m (Shiklomanov and Rodda, 2003). Of these global water resources about 97.20% is saline water, mainly in oceans and only 2.80 % is available as fresh water. Out of 2.80% fresh water, about 2.20% and 0.60% water are available as surface water and groundwater, respectively. Even out of the 2.20% of surface, about 2.15% is confined in glaciers icecaps and only 0.01% (1.36×104 million ha-m) is available in lakes and streams, the remaining 0.04% is being in other forms. Out of the 0.60% of stored groundwater, only about 0.25% (34×104 million ha-m) can be economically extracted with the present drilling technology (Deshpande, 1963). Most of the developing countries, population depend on groundwater for drinking, irrigation and domestic water uses, but yet the groundwater quality and its management have not received much attention. Millennium Development Goals (MDG) is an ambitious agenda for reducing poverty and improving lives that world leaders agreed on at the Millennium Summit in September, 2000. Of the eight goals, ensure environmental sustainability is the most important goal. The MDG have attempted to address the current unacceptable levels of lack of access to safe drinking water by aiming to halve the proportion of people without sustainable access to safe drinking water by 2015. Due to the ever-increasing demand for drinking and irrigation water and inadequate of surface water, the importance of groundwater is increasing exponentially every day. At the same time intense urbanization has placed a high demand on groundwater resources in arid and semi arid regions as a result groundwater quality has been deteriorated (Jalali, 2005). Groundwater quality comprises of the physical, chemical and biological qualities. A detailed geochemical study of groundwater is used to understand the role of various elements in watersheds, including all the major ions such as Na, K, Ca, Mg, Fe and As. Hydro-geochemical composition of groundwater can also be indicative of its origin and history of the passage through underground materials with which water has been in contact. Groundwater contains dissolved minerals from the soil layers during recirculation through which it passes. It may also contain some harmful contaminants through the process of seepage from the surface water and biological activities. The water bodies are continuously subjected to a dynamic state of change with respect to litho logical characteristics and geo-climatic conditions. This dynamic balance in the aquatic system is upset by human activities, resulting in contamination or pollution which is unsustainable development.

The quality of groundwater is equally important to its quantity owing to suitability and intended use of water for various purposes. The variation of groundwater quality in an area is a function of physical, chemical and biological parameters that are greatly influenced by geological formations and anthropogenic activities (Jiang and Yan, 2010; Nisi *et al.,* 2008; Perumal and Thamarai, 2008; Singh and Chandel, 2006; Subramani *et al.,* 2005a; Tatawat and Chandel, 2008).

1.8 Scope of the research

Consumption of water per capita is one of the major indicators of life-standard in modern and civilized society. In Bangladesh about 75% irrigation water is being supplied from groundwater. Therefore, the assessment of groundwater potentiality, exploitation and over drawl impact on environment has great important for sustainable water resource management. The groundwater potentiality of groundwater in Chapai Nawabganj district has been assessed principally considering specific yield, area and number of Deep Tubewells (DTWs) in the study area. A number of reports showed groundwater level depletion in the area has threatened crop production in the future. Therefore a detailed research work is imperative to understand the relation among rainfall, recharge capability and groundwater level fluctuation in the area as well as to predict environmental impact due to groundwater extraction for irrigation. The study results would have a great impact on sustainable groundwater resource management which would help our agriculture sector to become more environmental friendly. This research program has considered rainfall, water level fluctuation and drilling log data, and water quality parameters of five Upazilas in Chapai Nawabganj district under the Barind tract in view of maintaining sustainable irrigation water supply to achieve food security as well as water resource management.

1.9 Aim and Objectives

The study aimed to characterize the existing groundwater environment and to conceptualize the impact of groundwater exploitation on environment.

The objectives of the study were to

- Calculate a preliminary estimation of run-off and infiltration.
- Evaluate the seasonal groundwater level fluctuation.
- Determine specific yield and storage capacity of the study area.
- Assess the groundwater exploitation in the area.
- Evaluate the seasonal variation of groundwater quality.
- Assess the environmental impact due to groundwater extraction for irrigation.

Chapter Two

Review of Literature

REVIEW OF LITERATURE

2.1 Review of Literature

The literature reports are vast as regards the most important and brilliant development of the extensive studies of groundwater potentiality, exploitation and over drawl impact. A substantial amount of investigations are related to evaluate groundwater potentiality and controlling groundwater quality based on hydro-chemistry. The following summarizes only the recent reports on the groundwater potentiality, exploitation, geochemistry, water type, dissolution of minerals etc so far published.

The groundwater resource is one of the key factors in making the country self sufficient in food production. Groundwater-irrigated agriculture plays an important role in poverty alleviation and has greatly increased food production. The country’s GDP is highly dependent on the development of water resources in general. Trends indicate that farmers are becoming increasingly productive as a result of enhanced access to irrigation through groundwater (BMDA, 2000). In this Northern part of the country, lied the Barind Tract of Bangladesh, mainly and mostly in the district of Rajshahi, Chapai Nawabganj and Naogaon. This tract lies in the Northwestern part of old Rajshahi district (i.e. Rajshahi, Nawabganj and Naogaon), is dissected in the west and nearly level in the east. Mainly the central and Northern part of the old district belong to this landscape, covering fourteen upazillas (Matin, 1991). Monsoon rainfall may be defined as a complex meteorological condition which exists in any given area and important individuality to the landscape of the area. Monsoon rainfall plays important role in water resources management, crop management, planning of location of industrial cities, defense planning, tourism and transport, air pollution studies and in fact almost all spheres of human activity (Aziz, Abdullah-ul-Masum, Asma ul Husna and Matin, 2002). Warnings of a groundwater crisis (with falling groundwater tables and polluted aquifers) have led to calls for urgent management responses. However, much of the discussion has been on the basis of anecdotal evidence (Brown and Halweil, 1998; Postel, 1999; Sampal, 2000). Groundwater continues to serve as a reliable source of water for a variety of purposes, including industrial and domestic uses and irrigation. The use of generally high-quality groundwater for irrigation (which is largely indifferent to water quality) dwarfs all other uses (Burke, 2002). Groundwater is one of the very precious natural resource of earth and is primary source of life that sustains all human activities. It is essentially required not only for the sustenance of the human life but also for the economic and social progress of a region. It constitutes a major portion of the earth's water circulatory system known as 'hydrologic system'. Although it is more dynamic renewable natural resource yet availability with good quality and quantity in appropriate time and space is more important (Chaudhary *et al.,* 1996). As groundwater cannot be seen directly from the earth's surface, so a variety of techniques can provide information concerning its potential occurrence. Several studies since early 1960's have been attempted to explain spatial variability of groundwater occurrence in different terrain conditions using technologies like aerial photography and geographic information system. Remote sensing from satellite has recently become a valuable tool that provide quick and baseline information on sub-surface water conditions. With this information, one can find out the factors controlling the occurrence potential and movement of groundwater such as litho logy, geological structures, geomorphology, soil, land use land cover and other related characteristics of the area. This data can be spatially integrated by means of geographic information system and finally groundwater potential zones can be delineated. In this field attempts have already been made in different parts of the country by various scholars like Chaudhary *et. al.,* (1996), Krishnamurthy *et al.,* (1996), Das *et al.,* (1997), Goyal *et al.,* (1999), Pratap *et al.,* (2000), Nag (2005), Vijith *et al.,* (2007), Suja *et al.,* (2009), Kumar Pradeep (2010) etc. They had arrived at groundwater prospects by deriving thematic layers from satellite data, Survey of India top sheets and by integrating them in GIS environment. Groundwater abstraction for dry-season irrigation which has taken place since 1970s in the GBM Delta (WARPO, 2000) and more recently in the Irrawaddy Basin and Mekong Delta (Dawe, 2005; FAO, 2006), serves to increase seasonality in shallow groundwater levels. The highly seasonal nature of the shallow groundwater systems in Asian mega-deltas complicates resolution of trends in groundwater levels and, hence, groundwater storage. Aquifers that are found within the geologically complex bedrock terrains in eastern parts of the country are of variable thickness and depth. Recent alluvium and upper part of the Dupi Tila sand of Pliocene-

Pleistocene age form shallow aquifers which are generally located within the depth of 100m below surface (Ahmed *et al.,* 2004).

Time-dependent variations in surface water stage in both fresh and salt water environments are acknowledged to strongly influence local groundwater flow (Cooper, 1959). Variations in surface water stage can arise from many natural and anthropogenic sources including: precipitation and flood events, tidal oscillation, wave induced displacement, dam releases, and associated reservoir drawdown. These stream stage fluctuations are known to influence hydraulic gradients in the region surrounding the stream. In fact, time varying surface water stage is frequently used to estimate aquifer hydraulic diffusivity (Ferris, 1952; Rowe, 1960; Pinder *et al.,* 1969; Reynolds, 1987; Swamee and Singh, 2003). More specifically, shallow ground water and surface water in glaciated regions are often strongly linked due to the relative position of the groundwater table to the land surface (Winter *et al.,* 1998). Short-term fluctuations of surface water bodies are an important control on groundwater flow in coastal environments (Glover, 1959; Reilly and Goodman, 1985) globally; irrigation is responsible for more than 65% of all fresh water withdrawals. At present, one quarter of world's irrigated land is supplied by groundwater and 75% of these lands are located in Asia Agriculture in Bangladesh was entirely dependent on surface water and monsoon rainfall prior to 1970. Now in Bangladesh 79.1% lands are supplied water in *Boro* season from underground source. Barind Tract is a physiographic unit located in north-western part of Bangladesh having gross area of 7727 sq km. Geographically this unit lies between 24° 20' N and 25° 35' N latitudes and 88°20' E and 89°30' E longitudes. Barind Tract made up of Pleistocene Alluvium also known as older Alluvium and floored by reddish brown sticky Pleistocene sediment. Madhupur Clay. Pleistocene Dupi Tila Sand act as aquifer in Barind Tract. Barind Tract was excluded during 3000 DTW installation programmed of BADC in North-west irrigation Project considering as low potential area for groundwater development. (Shamsudduha *et al.,* 2011; UNDP, 1982; BADC, 2010; Ali, 2011; IRBD, 1970; Rasheed, 2008; Ahmed and Hossain, 2006).

Most of the Earth's liquid freshwater is found, not in lakes and rivers, but is stored underground in aquifers indeed; these aquifers provide a valuable base flow supplying water to rivers during periods of no rainfall. They are therefore an essential resource that requires protection so that groundwater can continue to sustain the human race and the various ecosystems that depend on it. The contribution from groundwater is vital; perhaps as many as two billion people depend directly upon aquifers for drinking water, and 40 per cent of the world's food is produced by irrigated agriculture that relies largely on groundwater. In the future, aquifer development will continue to be fundamental to economic development and reliable water supplies will be needed for domestic, industrial and irrigation purposes. After the establishment of Barind Integrated Area Development Project (presently 'Barind Multipurpose Development Authority'), a large number of DTWs has been installed sequentially to bring the seasonal fallow land under *Boro* rice cultivation. The area is bringing green during crop season at the cost of mining groundwater reserve. This happens due to insufficient recharge which is caused by low rainfall and its erratic distribution throughout the year. Sustainability of groundwater is a function of recharge (Devlin and Sophocleous, 2005: Sophocleous and Devlin, 2004). Human's overrates of groundwater distort the natural recharge-discharge equilibrium in addition. Climate variability causes changes in rainfall patterns and groundwater recharge groundwater management practices should generally be based on the sustainable-yield concept. Groundwater yield can be regarded as sustainable if it is used in a manner that it can be maintained for a long time without causing adverse environmental economic or social consequences (Alley and cake 2004). Since the capacity of the atmosphere to hold water increases exponentially with its temperature, evaporation and transpiration rates will increase. Temperature changes are also expected to affect crop communities by changing the length of the growing season (Alward *et al.,* 1999). Other relevant climate variables such as cloudiness, humidity and windiness are also likely to be linked to the changes in temperature (Gleick 1987; Komuscu *et al.,* 1998). If global warming occurs as projected, the global temperatures will continue to rise between 1.4 and 5.8°C by 2100 due to the emissions of greenhouse gases (McCarthy *et al.,* 2001).

The change of temperature and rainfall patterns will directly deplete soil moisture which can greatly reduce agricultural yield (Rosenzweig and Hillel 1998; Ojima *et al.,* 1999) and also causes more demand for irrigation. For example, in Syria, a waterscarce area, groundwater is estimated to constitute more than 50% of the total volume of irrigation water (JICA, 1997; Jumaa *et al*., 1999); approximately 21% of the cultivated land is irrigated, 60% with groundwater and 40% with surface water (SMAAR, 1999). Although Syria's annual per capita water availability is less than 1000 m 3, 90% of Syria's current water withdrawal is used for irrigation (Wakil, 1993). Understanding climate variability and change is vital for society and ecosystems, particularly with regard to complex changes affecting the availability and sustainability of surface-water and groundwater resources (Dragoni and Sukhija, 2008). The potential effects of climate variability and change on water resources are well recognized globally and have been identified as a major issue facing the availability of groundwater resources in the United States (Alley *et al.*, 1999). Climate variability and change can affect the quantity and quality of various components in the global hydrologic cycle (Loáiciga *et al.,* 1996; Sherif and Singh, 1999; Milly *et al.,* 2005). The components of the surface hydrologic cycle that may be affected include atmospheric water vapor content, precipitation and evapotranspiration patterns, snow cover and melting of ice and glaciers, soil temperature and moisture, and surface runoff and streamflow (Bates *et al.,* 2008). Such changes to the surface components of the global hydrologic cycle will likely influence the subsurface hydrologic cycle within the soil, unsaturated zone, and saturated zone, and may affect recharge, discharge, and groundwater storage of many aquifers worldwide (Timothy R. Green, U.S. Department of Agriculture, written commun., 2009). Understanding the potential effects of climate variability and change on groundwater is more complex than with surface water (Holman, 2006). Groundwater-residence times can range from days to tens of thousands of years or more, which delays and disperses the effects of climate and challenges efforts to detect responses in the groundwater to climate variability and change (Chen *et al.,* 2004).

Climate variability on these time scales is often the result of ENSO, PDO, and AMO and can have substantial influence on recharge, discharge, and water-table fluctuations in many aquifers, including the High Plains aquifer (Gurdak *et al.,* 2007; McMahon *et al.,* 2007; Gurdak, 2008; Gurdak *et al.,* 2009). Response of groundwater levels can be striking when climate variability from ENSO, PDO, and AMO are coincident in a positive or negative phase of variability. Such responses have been identified in aquifer systems of the Southwestern United States (Hanson *et al.,* 2004, 2006) and a number of other aquifers worldwide (Ngongondo, 2006), including those in many small, tropical islands in the Pacific, Indian, and Atlantic Oceans (White *et al.,* 2007). The observed irregular variations in hydrologic time series (such as precipitation, air temperature, stream flow, and groundwater levels) reflect a range of natural and human climate stresses (Hanson and Dettinger, 2005). Northern part of Bangladesh is now facing water scarcity problems in both agriculture and secured livelihood (Alice Mbugua, 2011). The Barind area in Rajshahi zone of Bangladesh greatly depends on ground water for irrigation and other municipal water requirement (Ahmeduzzaman *et al.,* 2012). A government report suggests that recharge to GW in the northwestern part varies from 210 to 445 mm. However, exploitation of GW in the area is going on the basis of one-third rainfall recharge hypothesis of BMDP, which is beyond the sustainable yield according to Islam and Kanumgoe (2005). Groundwater is one of the most valuable natural resources, and supports human health, economic development and ecological diversity. Due to its several inherent qualities (e.g. consistent temperature, widespread and continuous availability, excellent natural quality, limited vulnerability, low development cost and drought reliability), it has become an important and dependable source of water supplies in all climatic regions including both urban and rural areas of developed and developing countries (Todd and Mays, 2005). As remote sensors cannot detect groundwater directly, the presence of groundwater is inferred from different surface features derived from satellite imagery such as geology, landforms, soils, land use/ land cover, surface water bodies, etc., which act as indicators of groundwater existence (Todd, 1980; Jha and Peiffer, 2006). The type and number of themes used for the assessment of groundwater resources by Geoinformatics techniques varies considerably from one study to another. In most studies, local experience has been used for assigning weights to different thematic layers and their features. Only (Shahid and Nath, 2002) used Saaty's Analytical Hierarchy Process (AHP) for normalizing the assigned weights. Ghataprabha sub basin of Krishna river in peninsular India has been facing a severe water shortage problem for both irrigation and domestic purposes over the past few years (GOK, 2008). Groundwater resources are being increasingly recognized as an invaluable but largely untapped resource for agricultural development in sub-Saharan Africa (SSA) where it offers a more food-secure alternative to rain-fed subsistence farming (FAO 2005; GIDA 2000, 2001; Masiyandima and Giordano 2007). Very little is currently known about the physical extent, accessibility, and development potential of the aquifer systems in SSA, but interest is growing and new developments are emerging across the continent (Ngigi 2009; Titus et al. 2009).

A hydrogeological domain map of the entire sub-Saharan Africa region at 1:40-M scale was prepared by BGS (MacDonald and Davies 2000) which delineated the occurrence of groundwater in SSA. These global/continent scale efforts have been supplemented by various country-scale studies such as for Ethiopia, for the purposes of assessing the availability of groundwater during drought (MacDonald et al. 2001). Geochemical studies of groundwater provide a better understanding of possible changes in quality as development progress (Bhardwaj *et al.,* 2010; Gupta *et al.,* 2008; Gupta *et al.,* 2009; Jalali, 2006; Nagaraju *et al.*, 2006; Sreedevi, 2004; Subba Rao, 2006). Geochemical process, occurring within the groundwater and their reactions with the aquifer materials, are responsible for changes in groundwater chemistry and quality (Drever, 1988; Hem, 1991; Subba Rao and Surya Rao, 2009; Wen *et al.*, 2008). So, it is impossible to control the dissolution of undesirable constituents in the waters once they enter into the ground (Johnson, 1979; Sastri, 1994). Many naturally occurring major and trace elements in drinking water can have a significant effect on human health either through deficiency or excessive intake (Frengstad *et al.,* 2001). Thus, it is necessary to understand the hydrochemical parameters of groundwater and hydro-geochemical properties of the aquifer to utilize and protect valuable water sources effectively and predict the change in groundwater environments. The study of quantity of water alone is not sufficient to solve the water management issues because of its uses for various purposes depend on its quality. Hence, the hydro-geochemical characters of groundwater in different aquifers over space and time have proven to be important in solving the problems (Atwia *et al.,* 1997; Ballukraya and Ravi, 1999; Panigrahy *et al.,* 1996; Ramappa and Suresh, 2000). Therefore, the fundamental knowledge of the controlling process in groundwater chemistry is a pre-requisite condition for rational management of water resources. Groundwater supplied from 75 DTWs through pipe networks of 512 km reticulated over an area of 93.34 square kilometers and also withdrawn from 3811 shallow tubewells in Rajshahi City (R WASA, 2013).

Groundwater water demand is increasing day by day in the City and the current water demand is likely to reach around 118,077 m3/day, where supply water is about 55,440 m3/day (R WASA) which would be 2,40,000 m3/day by 2020 (DDC, 2002). About 70% of the population has access to pipe water (supply water) and the rest (30%) of demand is mitigated through shallow tube wells in the City area (R WASA, 2013). But the most unfortunate thing is that the tap water is being supplied without any treatment. Recently a surface water treatment plant has been established at Shampur in the City which cover about 10% of the total supply water. A number of research works were carried out on geochemistry of groundwater (Balasubramanian and Sastri, 1994), groundwater level fluctuation and quality monitoring, and its suitability for drinking and agriculture purposes (Subramani *et al.,* 2005a) and the occurrence of various rock types and their mineral composition (Subramani *et al.,* 2005b). A number of studies on groundwater quality with respect to drinking and irrigation purposes have been carried out in the different parts of the world including Bangladesh (Lakshmanan *et al.,* 2003; Mondal and Singh, 2004; Rabemana *et al.,* 2005; Das and Kaur, 2007; and Sadashivaiah *et al.,* 2008). The reports showed the analysis of major cations such as Na, Mg, K, Ca and anions including HCO_3^-, Cl^-, SO_4^{2-}, HNO_3^- and physical parameters i.e. pH, EC, TDS and TH are important for drinking purpose. Groundwater quality determination can be evaluated by various softwares (AQUACHEM, PHREEQC etc.) and diagrams such as Chanda, Dourov, Piper, Stiff (Chadha, 1999; Durov, 1948; Piper, 1944; Stiff, 1951) etc. Arsenic is viewed as being synonymous with toxicity. Arsenic contamination in groundwater is one of the biggest natural calamities**,** which has become threat to human health throughout the world. High arsenic concentrations have been reported recently in the USA, China, Chile, Bangladesh, Taiwan, Mexico, Argentina, Poland, Canada, Hungary, Japan and India. Among 21 countries in different parts of the world affected by groundwater arsenic contamination, the largest population at risk is in Bangladesh followed by West Bengal in India. Arsenic is considered a highly toxic element and abundant in our environment with both natural and anthropogenic sources (Smedley and Kinniburgh, 2002). Nickson *et al.,* (1998) reported that as many as million water wells drilled into Ganges alluvial deposits in Bangladesh and India (West Bengal) may be contaminated with arsenic. Arsenic contamination level in groundwater in many parts of the world has aroused attention due to it much higher concentrations than that of the World Health Organization's (WHO) drinking water standard. This situation has become more serious in Bangladesh, India (West Bengal), and Nepal in the Indo-region as a result of resource pressures from growing populations as well as surface water contamination (Kanel *et al.,* 2005; Smedley and Kinniburgh, 2002). Many studies have revealed that arsenic in groundwater, even at trace levels has proven to be harmful to human health and the environment. Hardness is very important property of water from its domestic application point of view. It is mainly an aesthetic concern because of the unpleasant taste. It also reduces the efficiency of soap and causes scale formation in pipes. Hard water also causes problem in boilers in industries however, it can be easily remove by the addition of slake lime [Ca(OH)2]. The World Health Organization did not have any recommendations for levels of Ca and hardness in drinking water (WHO, 2008). However, researchers have suggested that a minimum of 20 mg/L (Novikov *et al.,* 1983) and an optimum of about 50 (40-80 mg/L) mg/L (Kozisek, 1992; Rachmanin *et al.,* 1990) calcium present in drinking water may be the most suitable for human consumption. Kozisek (2006) showed that there is a higher risk of gall stones, kidney stones, urinary stones, arthrosis and arthropathies in populations supplied with water of hardness higher than 300 mg/L (Kozisek, 2006). According to WHO report (2007), 1.1 billion people lack access to an improved drinking water supply and 88% of the 4 billion annual cases of diarrheal disease are attributed to unsafe water and inadequate sanitation and hygiene, and 1.8 million people die from diarrheal diseases each year. The report also illustrate that the estimated that 94% of these diarrheal cases are preventable through modifications to the environment, including access to safe water. It is true that water borne infections are responsible for more than 80% of the diseases in all over the world. Whenever there is contamination of drinking water sources and water logging after rain there is in an outbreak of infection. Hazardous heavy metal contamination of groundwater is one of the most important environmental problems throughout the world.

A number of reports were found available on the internet, journals and books about arsenic contamination of groundwater in Bangladesh, related health hazards and mitigation measures (Chakravarty *et al.,* 2002; Chakraborti *et al.,* 2010; Van Halem *et al.,* 2010; Kongkea *et al.,* 2010; Karim, 2000; Meng *et al.,* 2001; Mostafa *et al.,* 2010, 2011; Needleman and Gatsonis, 1990; Nickson *et al.,* 1998;, Selim *et al.,* 2010). Hence, heavy metals in groundwater are injurious to human so, the remediation of hardness, arsenic and other heavy metals from drinking water is imperative to save people from its harmful effects. Because treatment of water can avoid much possible water borne diseases like cholera, typhoid, jaundice and so on. A number of reports have found on arsenic analysis and related contamination of groundwater in Rajshahi City area (Ahmed *et al.,* 1999; Ahmed *et al.,* 2002; BAMSAW, 2003; Chowdhury, 2004; Hossain, 1997; Sarkar and Heijnen, 2000; Uddin, 1999). Reports of arsenic in groundwater analyses revealed that about 27% samples of shallow tubewells contained arsenic (As) above Bangladesh standard for drinking water (0.05 mg/L) and about 46% samples were above the WHO guideline (0.01 mg/L) (BGS and MML, 1998; BGS and DPHE, 2001). A survey conducted by BAMWSP (2003) reported that 4 out of 25 pumps were found contaminated with arsenic above 0.05 mg/L in Rajshahi City. Thus, the presence of heavy metals, toxic chemicals, bacteria in drinking water need to be treated to save human life. The above literature review shows that much work has been done on groundwater uses for irrigation and its environmental impacts on environment. However, a few numbers of reports have been published on irrigation water supply in Barind tract and its consequence for sustainable water management.

Chapter Three
Materials and Methods

MATERIALS AND METHODS

The demand for water is increasing significantly due to population growth and economic development. It originates from three main sources, namely, agriculture, industrial uses and human consumption. The booming demand for crop production in particular is increasing the demand for water. Effective water resource management is critical to facilitating sustainable water use.

Groundwater is the major source for irrigation and domestic purposes in Bangladesh. With the increase in demand for water for competing uses, it is difficult to meet the entire demand from a single source and it is a challenge to plan and manage the different water resources. Among the two major water resources, surface and ground water, it is the ground water resource, which needs to be managed carefully, especially in drought prone areas.

The experimental and mathematical methods are required to assess the potential and exploitation of groundwater and the actual use of water by various crops in the study area. A critical study is carried out on the different methods of estimating the groundwater potentiality and exploitation, and compared arriving at the most suitable technique for practical utility. In this work, four methods of estimating groundwater recharge were studied viz., yearly water level fluctuation, ten year average water level fluctuation, fluctuation between the lowest and highest water levels over ten years and fluctuation in monsoon seasons. The results of this study help in accurate prediction of groundwater availability, which in turn may avoid groundwater over exploitation and help restore the aquatic eco-systems.

3.1 Study area

Barind, the name derived from a Persian word called Barinda means, land of small hillocks. Since the same typical hillock features are evident in this region the tract is named as Barind. Many other characteristics influenced this type of land, one of the salient features of this tract in its non-flooding characteristics. It was assumed that the region is not feasible for the ground water development due to non-availability of required aquifer. Also availability of surface water for irrigation purpose in Barind tract is very limited. However this tract has got the great potentialities in adding to a great extent to the granary of the country. Very recently Barindra Multipurpose Development Authority (BMDA), Rajshahi is so far successful to prove the potentiality and extraction capability of the tract.

Barind area is located in the northwestern part of Bangladesh consisted of most parts of six districts, namely Chapai Nawabganj, Rajshahi, Naogaon, Joypurhat, Bogra, Dinajpur and Rangpur. The area is situated in 24-23 to 25-15 N and 88-02 to 88-57 E. The groundwater overexploitation has caused the water table depletion to the extent of not getting fully replenished by the rainfall recharge. The irrigated water exploration in the area is increasing day by day, eventually the groundwater aquifer may be exhausted that will have certain impact on environment. Considering the Barind area and its irrigation project, the study has confined at a specific part, i.e., Chapai Nawabganj district of the Barind Irrigation Project. The district consists of five Upazilas, namely Nawabganj, Shibgonj, Nachole, Gomastapur and Bholahat and it lies under the Barind tract and has an area of 1744.33 km². The main rivers of the district are the Ganges and Mahanadi. Detailed information of five Upazilas of Chapai Nawabganj District in Barind area is shown in Table 1.

In Chapai Nawabganj district, Shibganj is the largest (525.43 sq km) Upazilas and it occupies 30.86% of the total area of the district and Bholahat is the smallest (123.52 sq km) Upazilas of the district.

Table 1

Detailed information of five Upazilas of Chapai Nawabganj District in given now

District Information									
Area (sq km)	Upazila	Municipality	Union	Mouza	Village	Population		Density (per sq km)	Literacy rate (%)
						Urban	Rural		
1702.56	5	3	45	785	1120	269087	1156235	837	35.9

Other Information of the district								
Name of Upazila	Area (sq km)	Municipality	Union	Mouza	Village	Population	Density (per sq km)	Literacy rate (%)
Nawabganj	451.80	1	14	174	211	452650	1002	38.1
Shibganj	525.43	1	15	199	392	508092	967	32.5
Nachole	283.68	-	4	201	197	132308	466	40.3
Gomastapur	318.13	1	8	166	227	240123	755	35.4
Bholahat	123.52	-	4	45	93	92149	746	39.2

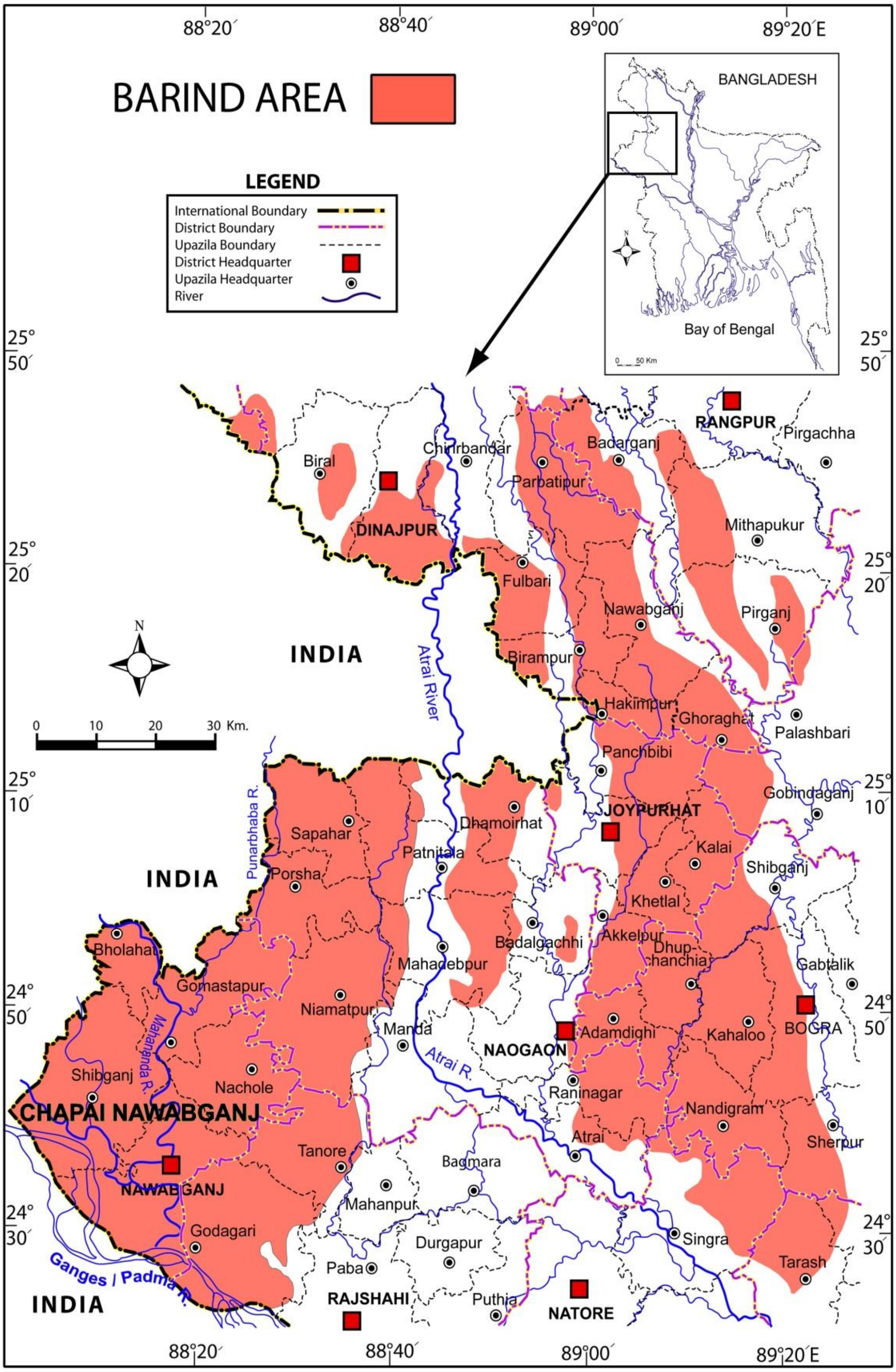

Figure 1 Study area map: Barind Area.

It is bounded by Indian state, West Bengal and Bangladesh on the north-south and west, and Rajshahi and Naogaon district on the east. The district is comprised of Barind tract, Diara and Char lands. The geographical map of the Barind area and Chapai Nawabganj district are shows in Figure 1 and 2, respectively.

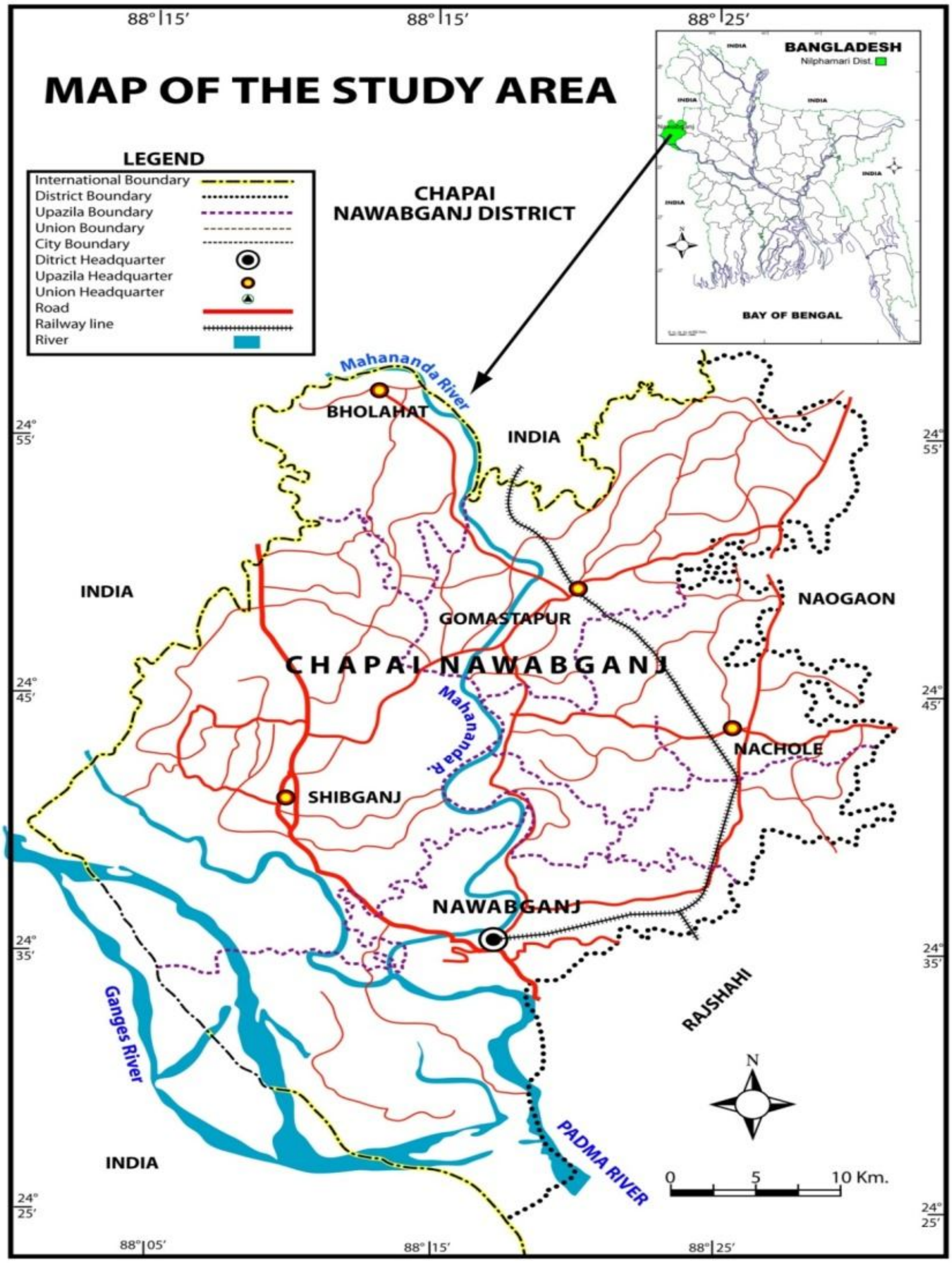

Figure 2 Sampling location map of Chapai Nawabganj district.

Table 2

Topographical information of Nawabganj Upazila

Sl. No.	Item	Quantity
a.	Total Area	451.80 km²
b.	Area of Barind Tract	20,137 Acres (16.90%)
c.	Area of Flood Plain	90,034 Acres (75.65%)
d.	Others	8,869 Acres (7.47%)
e.	Total Population	3,15,696 (1981)
f.	Total no. of DTW installed (Up to 2011)	213
g.	Time Zone	BST (UTC+6)
h.	Location	24.6000° N 88.2667° E

Above information indicate that the Upazila has 90,334 acres of Ganges Flood Plain, 20,137 acres of Barind Tract both broadly and closely dissected terrace are found.

Water samples were collected from five different locations of the Upazila and are shown in Figure 3.

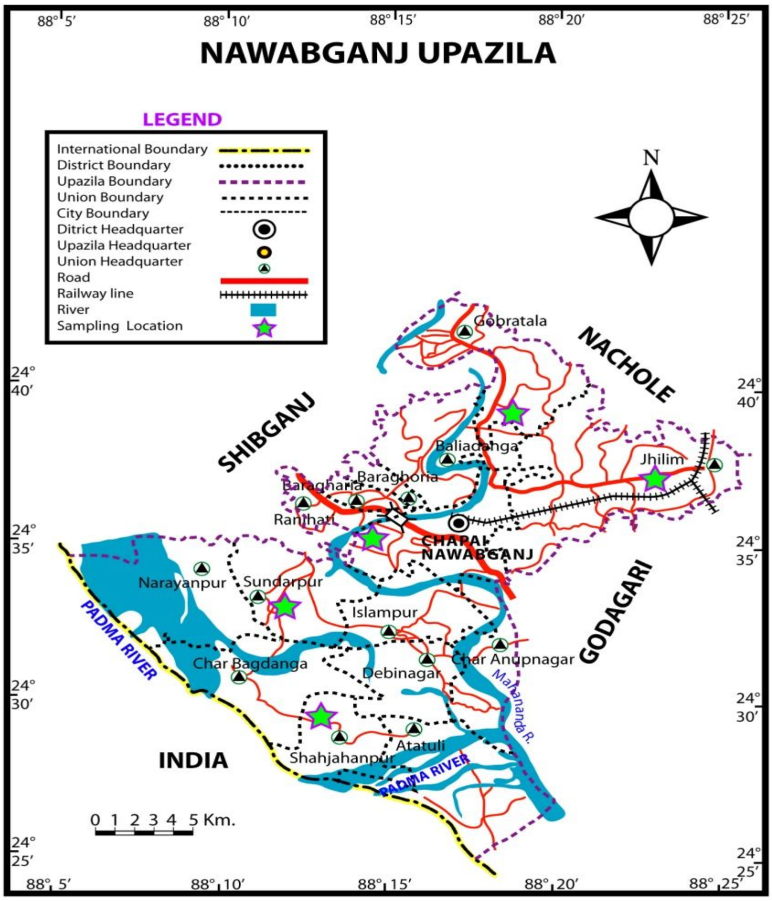

Figure 3 Sampling location map of Nawabganj Upazila, Chapai Nawabganj district.

Table 3

Topographical information of Shibganj Upazila

Sl. No.	Item	Quantity
a.	Total Area	525.43 km²
b.	Area of Barind Tract	0.0 Acres (0.0%)
c.	Area of Flood Plain	1,26,054 Acres (97.0%)
d.	Others	3875 Acres (3.0%)
e.	Total Population	422,347 (1991)
f.	Total no. of DTW installed (Up to 2011)	243
g.	Time Zone	BST (UTC+6)
h.	Location	24.6833° N 88.1667° E

Above information indicates that the Upazila has 94,697 acres of land is of Ganges Flood Plain and 36,773 acres of mixed Ganges and Mahananda meander floodplain.

Water samples were collected from five different locations of the Upazila and are shown in Figure 4.

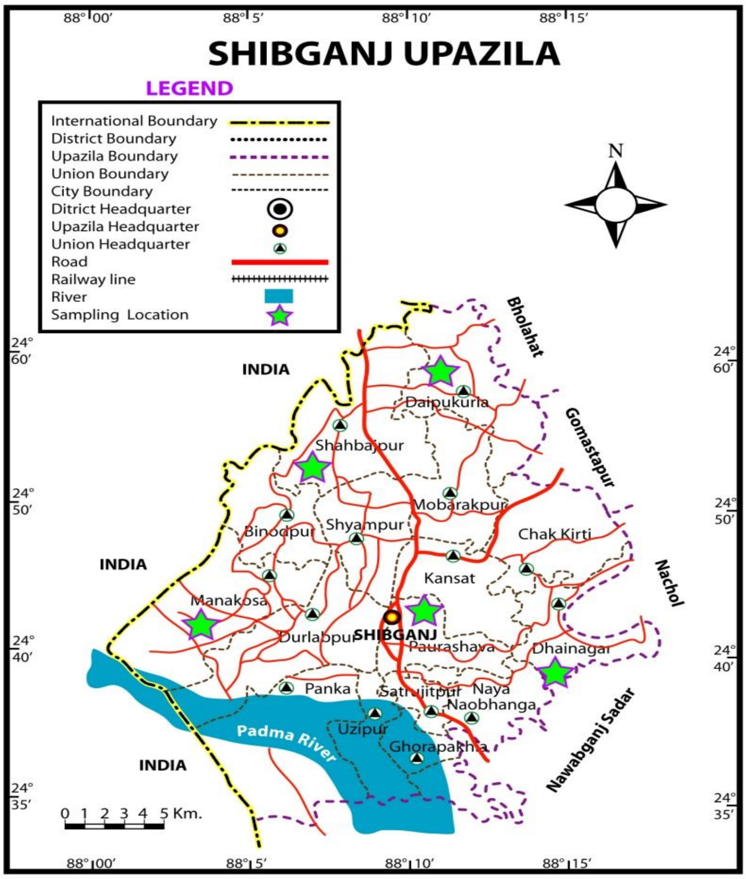

Figure 4 Sampling location map of Shibganj Upazila, Chapai Nawabganj district.

Table 4

Topographical information of Nachole Upazila

Sl. No.	Item	Quantity
a.	Total Area	283.68 km²
b.	Area of Barind Tract	61,953 Acres (89.63%)
c.	Area of Flood Plain	6,584 Acres (9.25%)
d.	Others	538 Acres (0.85%)
e.	Total Population	74,888 (1981)
f.	Total no. of DTW installed (Up to 2011)	543
g.	Time Zone	(BST (UTC+6)
h.	Location	24.7292° N 88.4194° E

Above information indicates that The Upazila has 6,584 acres of Ganges Flood Plain, 9,785 acres of Level Barind Tract and 52,168 acres of broadly and closely dissected Barind.

Water samples were collected from five different locations of the Upazila and are shown in Figure 5.

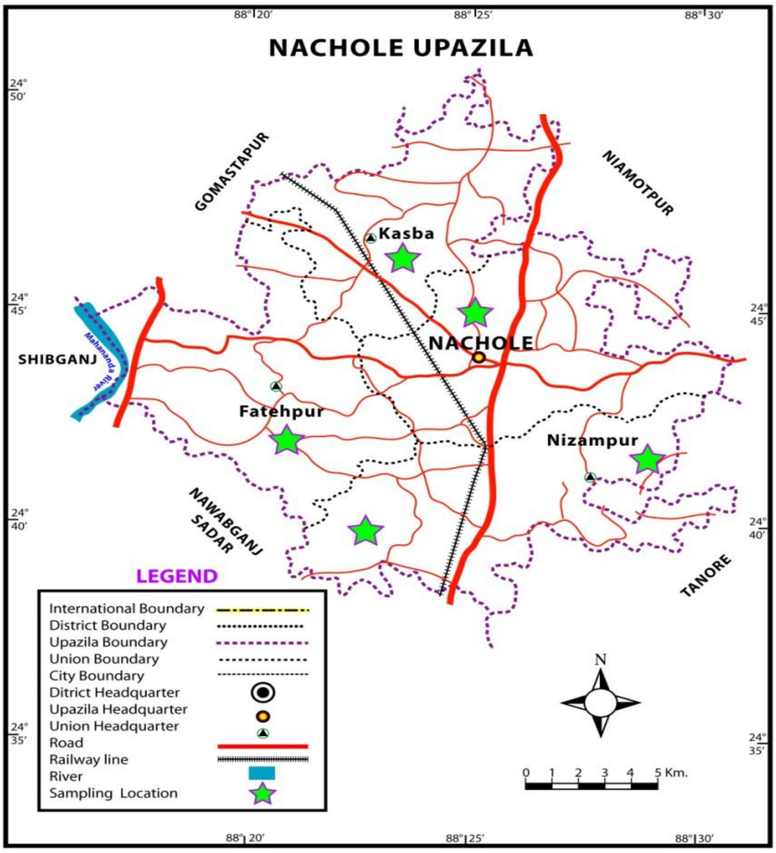

Figure 5 Sampling location map of Nachole Upazila, Chapai Nawabganj district.

Table 5

Topographical information of Gomastapur Upazila

Sl. No.	Item	Quantity
a.	Total Area	318.13 km²
b.	Area of Barind Tract	37,037 Acres (46.92%)
c.	Area of Flood Plain	40,425 Acres (51.23%)
d.	Other	1,450 Acres (1.85%)
e.	Total Population	321,792 (1991).
f.	Total no. of DTW installed (Up to 2011)	401
g.	Time Zone	(BST (UTC+6)
h.	Location	24.7750° N 88.2833° E

Above information indicates that the total 26,635 acres of land is of Ganges Flood Plain with 13,790 acres being old flood plain, 26,792 acres are borehole dissected Barind Tract and 9,931 acres of closely dissected.

Water samples were collected from five different of the locations Upazila and are shown in Figure 6.

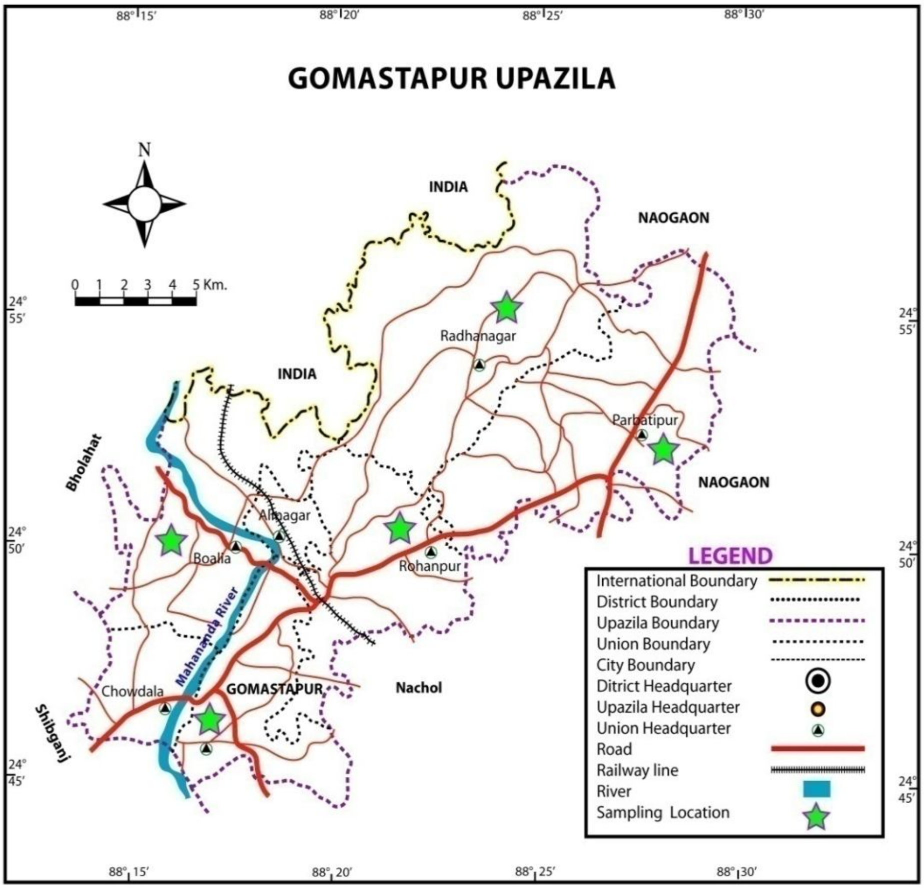

Figure 6 Sampling location map of Gomastapur Upazila, Chapai Nawabganj district.

Table 6

Topographical information of Bholahat Upazila

Sl. No.	Item	Quantity
a.	Total Area	123.52 km^2
b.	Area of Barind Tract	3,592 Acres (11.22%)
c.	Area of Flood Plain	27,592 Acres (86.23%)
d.	Other	180 Acres (0.55%)
e.	Total Population	200,000
f.	Total no. of DTW installed (Up to 2011)	246
g.	Time Zone	BST (UTC+6)
h.	Location	24.9389° N 88.2028° E

Above information indicates that the Upazilla is overlain with 285 Acres of younger meander floodplain, 27,309 acres of mixed Ganges-Mohananda meander floodplain, 3592 Acres of Barind Level led covered terrace.

Water samples were collected from five different locations of the Upazila and are shown in Figure 7.

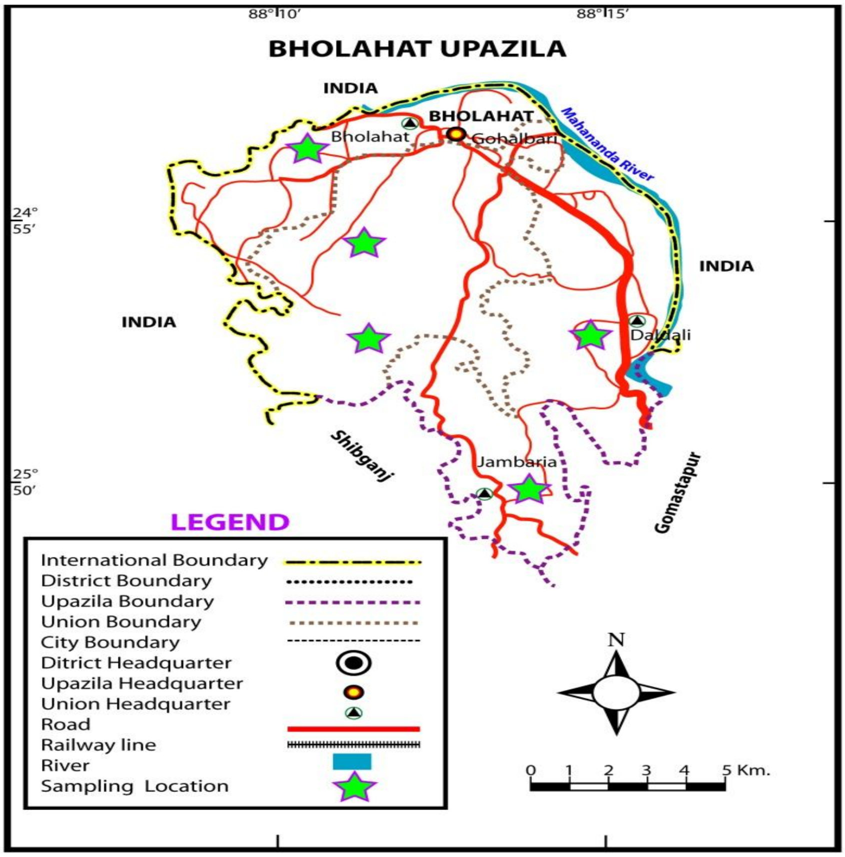

Figure 7 Sampling location map of Bholahat Upazila, Chapai Nawabganj district.

3.2 Data Collection

The study largely considered secondary data of groundwater level fluctuation and rainfall for the period from 2002 to 2011 collected from the head office of BMDA. It also collected evopotranspiration data from the Institute of Water Modeling (IWM), Dhaka of the study area for the same period.

3.3 Precipitation

It is general from of atmospheric moisture, which emanates from the clouds and ultimate falling over the land surface. In other words the precipitation can be defined as the total amount of water falling from the atmosphere in the form of rain, snow, mist etc. On the earth which is useful for human being. It is measured in from of depth of the water occurred on a horizontal land surface due to precipitation in a particular day, month or year. The phenomena from its formation and reaching it to the ground are tackled by the hydrology. Precipitation is usually expressed in terms of vertical depth of water that accumulates over the land surface at particular time period. It is generally expressed in millimeter in metric unit. The measurement of precipitation is performed by using an instrument known as rain gauge.

Rain gauge records the rainfall event occurring over the ground surface. The observations were recorded at the end of 24 hours, but in case of heavy rainfall interval can be changed.

The collected rainfall samples were measured with the help of graduated cylinder which was obtained in terms of rain fall volume. It was converted in the form of depth dividing by the rain fall volume with aperture area of the gauge. It is given as follows:

$$\text{Rainfall depth (mm)} = \frac{\text{Volume of water collected (mm}^3\text{)}}{\text{Aperture area of the gague (mm}^2\text{)}}$$

3.4 Run-off

The portion of precipitation which appears in the surface stream of either perennial or intermittent nature is called runoff. This is the flow collected from a drainage basin and appearing at an outlet of the basin. The runoff is more uniform compared to precipitation, while the precipitation is sporadic and irregular in nature. This contrast between precipitation and runoff is due to the storage effects of the surface layers of the earth. Runoff was calculated using the following equation,

$$R = K_b \times P \qquad 2.1$$

where

P and K_b are the rainfall and the runoff coefficient, respectively.

3.5 Evaportranspiration

It is a combine term of evaporation and transpiration, defined as the total loss of water through evaporation and transpiration from the plants. The term transpiration is associated with the plant and is referred by the water lost through the plant during respiration process. The evaportranspiration occurs only when plant is being grown in the soil. Practically, it is not possible to separate the evaporation and transpiration losses from the total water lost by the plants, therefore, water lost by the plants grown is expressed by a single term evapotranspiration.

All water surface and subsurface, released into the atmosphere by processes of evaporation and transpiration is consumptive use or evapotranspiration. To compute this discharge from a given basin, it is first necessary to make a land used or cultural survey to yield the amount of each type of water-consuming area. Aerial photographs are helpful for this task. Unit values of consumptive use must then be determined. For water surfaces local evaporation records should be employed. Urban and industrial area requires careful estimates from sample of representative areas using metered deliveries and sewage outflows. Multiplying the unit value of consumptive used by the corresponding acreage gives the water consumption for each area, the sum of these products yields the total consumptive use over the basin. The evapotranspiration separation data were collected from IWM office Dhaka and were used to determine infiltration.

3.6 Infiltration

Water entering the soil at the ground surface is called infiltration. It is the process by which water enters the surface strata of the earth. The infiltrated water first meets the soil moisture deficiency, if any, and further the excess water moves vertically downwards to reach the groundwater table. Infiltration was calculated using the following equation:

$$I = P - ET - R \qquad 2.2$$

where

I, P, ET and *R* indicate the infiltration, rainfall, evapotranspiration and runoff, respectively.

3.7 Procedure of Data Analysis

The collected secondary data were analyzed and Figures were drawn using the following steps-

i) Microsoft Excel software was used to analyze the monthly groundwater level fluctuation data of five Upazilas.

ii) The above software was also used to analyze ten years groundwater data to get the average fluctuation of individual Upazila

iii) The specific yield of each Upazila was determined by Cooper-Jacob method using Math lab software.

iv) The storage of groundwater was then ascertained by the following mathematical formula:

$$\text{Storage of groundwater} = S_y \times f \times a \qquad 2.3$$

where

S_y = *Specific Yield*

f = *Fluctuation of water table*

a = *Area of respective upazila*

v). Groundwater withdrawal was determined as follows:

No. of deep tubewells (DTWs) capacity of DTWs running hour of each DTW per year.

3.8 Determination of specific yield

The Specific Yield Sy of a soil or rock is the ratio of the volume of water after saturation was is drained by gravity to its own volume.

$$S_y = W_y/V \qquad 2.4$$

where

W_y is the volume of water drained

Values of specific yield depend on grain size, shape and distribution of pores, compaction of the stratum, and time of drainage. Individual value for soil or rock can vary considerably from these values. It should be noted that fine grained materials yield little water whereas the course-grained materials permit a substantial release of water serve as aquifers. In general specific yield for thick unconsolidated formations tend to fall in the range of 7-15 percent, because of the mixture of grain sizes present in the variation strata furthermore they normally decreases with depth due to compaction.

Specific yield can be measured by a variety of technical involving laboratory; field and estimating technique method.

There are several methods are using to determine the specific yield e.g.

1. Cooper-Jacob method
2. Chow method
3. Theis method

However, the study considered the Cooper-Jacob method to ascertain the specific yield because the method is more mathematical and computer based programming i.e., the software MATLAB.

3.9 Copper-Jacob Method of Solution

It was noted by Cooper and Jacob that for small values of radius of influence (r) and large values of time (*t*), u (*where* $u = r^2S/4Tt$) is small, so that the series terms in equation become negligible after the first two terms. As a result, the drawdown can be expressed by the asymptote:

$$S = \frac{Q}{4\pi T}\log(-0.5772 - In\frac{r^2S}{4Tt}) \quad 2.5$$

Rewriting and changing to decimal logarithms, equation now becomes

$$S = \frac{2.30Q}{4\pi T}\log\frac{2.25Tt}{r^2S} \quad 2.6$$

Projecting this line to S = *0* where $t = t_0$

$$0 = \frac{2.30Q}{4\pi T}\log\frac{2.25Tt_0}{r^2S} \quad 2.7$$

And it follows that

$$\frac{2.25Tt_0}{r^2S} = 1 \quad 2.8$$

There fore

$$S = \frac{2.25Tt_0}{r^2} \quad 2.9$$

A value of T can be obtain by noting if $t/t_0 = 10$*, then log* $t/t_0 = 1$*; Therefore replacing S by Δs.*

where Δs is the drawdown difference per log cycle of t, equation 2.6 becomes

$$T = \frac{2.30Q}{4\pi\Delta S} \quad 2.10$$

where

T = Transmissivity

Δs = Drawdown difference per log cycle

t_0 = Zero Drawdown

S = Specific Yield

Q = Discharge

r = Radius of influence

Thus the procedure is first to solve for *T* in Equation 2.10 and then solve specific yield *S* in Equation 2.9.

To calculate the drawdown difference per specific yield of each Upazila of Chapai Nawabganj district from drawdown curve is plotted from pumping test data. Using the equation suggested by Cooper and Jacob, specific yield was calculated and total groundwater storage and annual extraction of water were determined.

3.10 Boring log data sample Collection

A total of five boring log samples were collected from five Upazilas of Chapai Nawabganj district. The boring log samples of different layers were collected from each Upazila and the sampling locations were: (a) Upazila: Nawabganj, Union: Jhilim, Mouza: Chattigram, J.L. No. 83, Plot No. 277. (b) Upazila: Shibgang, Union: Pukuria, Mouza: Devigonj, J.L. No. 31, Plot No. 954. (c) Upazila: Nachole, Union: Fatepur, Mouza: Takahara, J.L No. 88, plot No. 572. (d) Upazila: Gomastapur, Union: Balie, Mouza: Kalinagar J.L. No. 133, Plot No. 248. (e) Upazila: Bholahat, Union: Gohalbari, Mouza: Gohalbari, J.L No. 21, Plot No. 7263.

3.11 Sieve Analysis

A sieve analysis is a commonly used procedure (Civil Engineering) to assess the particle size distribution (also called *gradation*) of a granular material. This method covers the determination of the particle size distribution of fine and coarse aggregates by sieving. A weighed sample of dry aggregates is separated through a series of sieves of progressively smaller openings for determination of particle size distribution in the test. This method was used primarily to determine the grading of materials proposed for use as aggregates or being used as aggregates.

Apparatus:

Balances: For aggregates readable to 0.1 g of the test load, whichever is greater, at any point within the range of use. For coarse aggregates, or mixtures of fine and coarse aggregates, readable and accurate to 0.5 g of the test load, whichever was greater, at any point within the range of used.

(ii) Sieves:

The Sieves should be mounted on substantial frames constructed in a manner that would prevent loss of material during sieving. In this study, the sieves mounted in frames larger than standard 203 mm (8 in) diameter was used for testing coarse aggregates.

(iii) Fine Aggregates:

The test sample of fine aggregates was weighed after drying approximately the following amount:

Aggregates with at least 95% passing a 2.36 mm (No.8) sieve – 100 gm

Aggregates with at least 85% passing a 4.75 mm (No.4) sieve and more than 5% retained on a 2.36 mm (No.8) sieve – 500 gm.

(iv) Course Aggregates:

The Weight of the test sample of coarse aggregates were conformed with the following:

Nominal Maximum Size Square Openings, mm(in.)	**Minimum Weight of Test Sample, Kg(lb)**
9.5 (3/8)	1 (2)
12.5 (1/2)	2 (4)
19.0 (3/4)	5 (11)
25.0 (1)	10 (22)
37.5 (1.5)	15 (33)
50 (2)	20 (44)
63 (2.5)	35 (77)
75 (3)	60 (130)
100 (4)	150 (330)
125 (5)	300 (660)
150 (6)	500 (1100)

(v) Precaution:

The following precautions were considered during the sieve analysis in order to get uniform particle size

(i) A suitable amount of materials were poured on a given sieve so that all particles have the opportunities to reach opening a number of times.

(ii) There was no force applied to any particle to pass through an opening.

3.12 Water Sample collection

A total of 50 representatives DTWs water samples were collected from 5 selected locations of each Upazila during the month of March (pre-monsoon) and October (post-monsoon), 2014. The samples were collected in 2 liter plastic bottles, which were pre-washed with dilute HCI and rinsed three to four times with distilled water. The water samples were collected after 10 minutes pumping of each DTWs to remove groundwater stored in the well. The Samples for metal analyses were acidified with HNO_3 and adjusted the pH <2, but the samples for analyzing physical parameters including pH, EC, total hardness (TH), total dissolved solids (TDS) and major anions were not acidified. Samples were labeled, sealed and transported to the laboratory and stored in a refrigerator at a temperature of about 4° C until the analysis was done. Bicarbonate and chloride were analyzed according to the standard procedures stated in American Public Health Association (APHA, 1995). For microbial analysis, water samples were collected in 250 ml capacity glass bottles, capped immediately and transported to the laboratory and stored in refrigerator at a temperature of about 4° C until the analysis was done.

3.13 Water sample preparation

200 ml water sample was digested with 5 ml of do-acid mixture (HNO_3:$HCIO_4$:9:4 ratio) on a hot plate and evaporated to one-fifth of its volume, and then it was allowed to cool. It was than filtered through what man No. 42 filter and made up to a volume of 50 ml by double distilled water.

3.14 Water sample analysis

The collected groundwater samples were analyzed for the parameters including temperature, pH, EC, TH, TDS, TSS and the concentrations of major cat ions and anions. Temperature, pH and EC were determined immediately after collection of the samples to avoid further contamination. TDS, TH and chloride were determined by using evaporation, standard EDTA and $AgNO_3$ method, respectively. Samples for Na, Mg, K, Ca, Mn, Fe, and As, ions analyzed using AAS (Simadzu AA-6800). SO_4^{2-} was analyzed using UV-visible Spectrophotometer (Rowell, 1994). CO_3^{2-} and HCO^{3-} were measured using titration method. Microbial parameters such as total coli from (FC) were determined by membrane filtration method. All experiments were conducted in triplicate to ensure accuracy and precision. All reagents used in this study were analytical grade chemicals.

i. Temperature, pH and EC

Temperature, pH and EC were measured in the field, immediately after sampling using potable alcohol thermometer, pH meter and EC meter (EC-210, HANA, Italy), respectively.

ii. Total Dissolved Solids (TDS)

At first a (150 ml) Pyrex beaker was taken and dried in an oven at 105° C for 24 hours and then allowed to cool. 100 m/L of water sample was filtered through what man 42 filter in the above beaker and it was evaporated to dry in an oven at 105°C for 24 hours.

$$\text{Total Dissolved Solids} = \frac{(A - B) \times 100000}{V} \qquad 2.12$$

where

A = Final weight of beaker (g)

B = Initial weight of beaker (g)

V = Volume (mL) of water sample taken = 100 mL

iii. Total Hardness (TH)

Total Hardness (TH) in water samples was determined by EDTA and the detailed of this method is given bellow:

A. Apparatus: Burette, pipette, stand, conical flask, volumetric flask.

B. Reagent: Erichorome Black T-indicator, NH_4C1, NH_3, $Na_2B_4O_7$. $10H_2O$.

(a) Erichorome Black-T indicator: Erichrome Black-T indicator was prepared by weighed out exactly 0.5 g of Erichrome Black-T and 100 g of NaC1 and it was mixed with 20 m/L of distilled water in a 100 m/L beaker by gradually warming. Finally, it was stored in a glass bottle for using 100 days.

(b) Ammonia Buffer: 20 g of borax ($Na_2B_4O_7$. $10H_2O$) was dissolved gradually in a 500 m/L volumetric flask and made up to the volume 400 m/L by distilled water. Again 5 g of NaOH and 2.5 g of sodium sulphide were dissolved in 50 m/L distilled water and mixed with previous borax solution. Than the solution thoroughly mixed by shaking and finally it was made up to the mark of the volumetric flask (500 m/L).

(c) Standard EDTA titrant, 0.01 M: 3.723 g analytical reagent grade EDTA di-sodium salt ($Na_2H_2C_{10}H_{12}O_8N_2$) was dissolved slowly in a 1000 m/L volumetric flask and made up to the mark with distilled water gradually. It was standardized against standard calcium solution.

C. Procedure:

100 m/L water sample was taken in a 250 m/L conical flask and added 1 m/L of ammonia buffer solution and 0.5 g Erichrome black-T indicator, subsequently. The standard EDTA titrant was slowly added, with continuous stirring until the color changed from wine red to blue. Noted the m/L of 0.01 MEDTA titrant used for titration.

D. Calculation:

Hardness ($CaCO_3$, mg/L)

$$= \frac{\text{Volume (mL) of EDTA used from burette}}{V} \times 100 \qquad 2.13$$

where

V= Volume (m/L) of sample taken =100 m/L

iv. Chloride ion (Cl^-)

The Chloride ion (Cl^-) in water samples was determined using $AgNO_3$ titration method, which describes as follows:

A. Reagents: $K_2Cr_2O_4$ indicator and 0.0141 N $AgNO_3$

***(a) Preparation of 5% $K_2Cr_2O_4$ (indicator)*:** 5% $K_2Cr_2O_4$ indicator was prepared by exactly taking 5 g $K_2Cr_2O_4$ in a 100 m/L volumetric flask and it was dissolved by 50 m/L distilled water. Then 0.0141 N $AgNO_3$ was did drop wise in the $K_2Cr_2O_4$

containing volumetric flask until the first permanent red precipitate was produced. Filtered the solution and finally it diluted by distilled water slowly and finally made up to the mark with the distilled water.

(b) Preparation of 0.0141 N $AgNO_3$: 2.397 g of AgNO3 was weighed out, transferred to a 1000 m/L volumetric flask and made up to the mark with distilled water gradually. The resulting solution was 0.0141 N. The solution was standardized against NaCl. Reagent-grade $NaCl^-$ was dried overnight and cooled at a room temperature. 0.25 g portions of $NaCl^-$ were weighed into Erlenmeyer flasks and it was dissolved by distilled water. Finally it was diluate up to the mark of 100 m/L by distilled water. In order to adjust the pH of the solutions, small quantities of NaHCO3 were added until effervescence ceased. About 2 m/L of $K_2Cr_2O_4$ was added and the solution was titrated to the first permanent appearance of red $K_2Cr_2O_4$

B. Procedure:

At first 100 m/L of water sample was filtered and taken in a 250 m/L conical flask. 1 m/L of $K_2Cr_2O_4$ indicator was added to the flask and shaken slowly. Then sample was titrated with 0.0141 N $AgNO_3$ until the brick red color was arrived indicating the end point. Noted the m/L of 0.0141 N $AgNO_3$ used for titration.

C. Calculation:

$$\text{Chloride } (Cl^-, \text{mg/L}) = \frac{(A \times N)}{V} \times 35450 \qquad 2.14$$

where

A = m/L of 0.0141 N $AgNO_3$ used for titration from burette

N = Normality of $AgNO_3$ = 0.0141 N

V = Volume of water sample taken=100 m/L

v. Sulphate ions (SO_4^{2-})

A sulphate ion ($SO4^{2-}$) in water samples was determined using Ultraviolet (UV) Spectrophotometric method, which describes as follows:

A. Apparatus: Spectrophotometer wave length at 420 nm silt.

B. Reagent:

(a) Buffer solution: The solution of buffer was prepared by taking exactly 30 g $MgC1_2.6H_2O$, 5 g sodium acetate ($CH_3COONa.3H_2O$), 0.111 g sodium sulphate (Na_2SO_4) and 20 m/L acetic in 1000 m/L volumetric flask. Then it was dissolved with the distilled water and shaken well. Finally, it was made up to the mark with distilled water.

(b) Barium chloride: $BaC1_2$ crystal 20 to 30 mesh was used to made uniform turbidity.

(c) Standard sulphate solution: The standard sulphate solution was prepared by weighed out exactly 0.1479 g anhydrous Na_2SO_4 and it was taken in a 1000 m/L volumetric flask. Then it was dissolved with the distilled water and finally, made up to the nark with distilled water, where 1 m/L = 100 ug (SO_4^{2-}).

C. Procedure:

(a). Formation of barium sulphate turbidity: 100 m/L water sample was taken in A 250 m/L Erlenmeyer flask an 20 m/L buffer solution was added and mixed with stirring apparatus. At the time of stirring a spoonful of $BaC1_2$ crystals was added and the solution was stirred for 1 minute.

(b) Measurement of turbidity: After stirring was poured in absorption cell of and turbidity was measured within 5 minutes.

(c) Preparation of standard curve: The proportions of 2, 4, 6, 8 and 10 mg/L of Na_2SO_4 solutions were taken in three different 1000 m/L volumetric flasks and distillated water was gradually added and thoroughly shaken and finally made up to the mark with distilled water. Absorbance of the water samples were determined by AAS. A standard curve was made by plotting the absorbance against the concentration.

D. Calculation:

$$\text{Sulphate } (SO_4^{2-}, \text{mg/L}) = \text{Concentration of } SO_4^{2-} \text{ (mg/L) from standard curve} \times \text{dilution factor} \quad (2.15)$$

vi. Carbonate ion (CO_3^{2-}) and Bicarbonate ion (HCO_3^-)

The carbonate ion (CO_3^{2-}) and bicarbonate ion (HCO_3^-) in groundwater samples was determined using titration method, which describes as follows:

The alkalinity in water samples is caused due to the presence of carbonate ion (CO_3^{2-}), and bicarbonate ion (HCO_3^-) and Hydroxide ion (OH^-). In this study CO_3^{2-} and HCO_3^- were determined.

A. Reagents: Phenolphthalein indicator, methyl orange indicator and 0.1 N HCI.

(a) Preparation of phenolphthalein indicator: Phenolphthalein indicator was prepared by exactly taking 0.5 g phenolphthalein in a 100 m/L volumetric flask and added 50% ethanol slowly and shaken well and finally made up to the mark with 50% ethanol. Then it was shaken well and finally stored in a glass bottle.

(b) Preparation of methyl orange indicator: Methyl orange indicator was prepared by exactly taking 0.5 g methyl orange in a 100 m/L volumetric flask and added demonized water slowly and shaken well and finally made up to the mark with demonized water. Then it was shaken well and finally stored in a glass bottle.

B. Procedure:

Each of 100 m/L of water sample was taken in two separate 250 m/L conical flasks. 2 drops of Phenolphthalein indicator was added to the first flask and no color was found indicated that phenolphthalein alkalinity (PA) was zero (0). So, CO_3^{2-} ion was absent in water sample. Then, 2 drops of methyl orange indicator was added to the 2^{nd} conical flask and shaken gradually and color was detected. The sample containing 2^{nd} flask was titrated with 0.1 N HC1 until the color changed to orange and it indicated the end point. It indicated that HCO_3^- ion was present in water samples noted the volume (m/L) of acid from the burette used for the titration.

C. Calculation:

$$\text{Total alkalinity (TA, CaCO}_3\text{, mg/L)} = \frac{A \times N \times 1000 \times 50}{V} \qquad 2.16$$

where

A = m/L of HCl used for titration with methyl orange indicator

N = Normality of HCl=0.1 N HCl

V = Volume of water sample taken=100 m/L

vii. Sodium (Na)

The sodium ion in ground water sample was determined using atomic absorption method, which describes as follows:

A. Apparatus: AAS wave length at 330.2 nm with 0.7 nm silt.

B. Reagent:

(a) 1000 mg/L standard solution: The standard solution of sodium ion was prepared by exactly taking 2.540 g of analytically (99%) NaC1 in a 1000 m/L volumetric flask and added distilled water slowly and shaken well and finally made up to the mark with distilled water.

(b) Suppressing agent: 0.1% potassium: 5.20 g of KC1 was dissolved in a 1000 m/L volumetric flask and made up to the mark with distilled water gradually. Than 100 m/L of 1% potassium ion solution was taken and diluted 1000 m/L with distilled water the final concentrated of 0.1% K. To reduce percentage of relative standard deviation (RSD), 2 drops of 0.1% potassium solution was used for maintained in every standard and sample.

C. Procedure:

(a) Sample preparation: 100 m/L water sample was taken in a beaker and added 2 m/L concentrated HNO_3 and 3mL concentration HCI. The beaker was heated 90-95°C on a hot plate and allowed to cool. Then samples were filtered through 0.45 um pore membrane filter. Finally, the volume was made up to 100 m/L with distilled water. Similar procedure was followed for the samples preparation of Mg, K, Ca, Mn, Fe, Cu, Zn, As, Cd and Pb.

(b) Standard curve: The proportion of 2, 5, 8 and 10 m/L Na ion contained standard solutions were taken in four different 1000 m/L volumetric flasks and distillated water was gradually added and thoroughly shaken and finally made up to the mark. Absorbance of the water samples were determined by ASS. A standard curve was made by plotting the absorbance against the concentration.

D. Calculation:

Sodium (NA, m/L) = Concentration of Na (mg/L)

from standard curve × dilution factor 2.17

viii. Potassium (K)

The potassium ion in water samples was determined using Atomic Absorption method, which describes as follows:

A. Apparatus: AAS wave length at 766.49 nm with 0.7 nm silt.

B. Reagent:

(a) 1000 mg/L standard solution: The standard solution of potassium ion was prepared by exactly taking 1.910 g of analytically pure (99%) KCI in a 1000 m/L volumetric flask and assed distilled water slowly and shaken well and finally made up the mark with distilled water.

(b) Suppressing agents: 0.1% potassium: 1 g of KC1 was dissolved in a 100 m/L volumetric flask and made up to the mark with distilled water gradually. To reduce percentage of relative standard deviation (RSD), 2 drops of 0.1% potassium solution was for maintained in every standard and sample.

C. Standard curve:

The proportions of 2, 8 and 10 m/L K ion contained standard solutions were taken in three different 1000 m/L volumetric flasks and distillated water was gradually added and thoroughly shaken and finally made up to the mark with distilled water. Absorbance of the water samples were determined by AAS. A standard curve was made by plotting the absorbance against the concentration.

D. Calculation:

Potassium (K, mg/L) = concentration of K (mg/L) from standard curve 2.18

ix. Calcium (Ca)

The calcium ion in water samples was determined using Atomic Absorption method, which describes as follows:

A. Apparatus: AAS wave length at 422.7 nm with 0.7 nm silt.

(*a) 1000 mg/L standard solution:* The standard solution of calcium ion was prepared by exactly taking 0.250 g of analytically pure (99%) $CaCO_3$ in a 1000 m/L volumetric flask and added distilled water slowly and shaken well and finally made up the mark with distilled water.

(b) Suppressing agents: 0.2% Lanthanum solution: The solution of 2% lanthanum was prepared by exactly taken 2 g of lanthanum chloride in a 100 m/L volumetric flask and added to the 3 m/L of 1M HC1. Again it was dissolved distilled water and finally, made up to the mark with distilled water gradually and shaken well. Then 10 m/L of 2% lanthanum was taken and diluted 100 m/L with distilled water to make the final concentrated of 0.2% lanthanum. That solution was used for maintained in every standard and sample.

C. Standard curve:

The proportions of 0.5, 1, and 2 m/L Ca ion contained standard solutions were taken in three different 1000 m/L volumetric flasks and distillated water was gradually added and thoroughly shaken and finally made up to the mark with distilled water. Absorbance of the water samples were determined by AAS. A standard curve was made by plotting the absorbance against the concentration.

D. Calculation:

Calcium (Ca, mg/L) = concentration of K (mg/L) from standard curve 2.19

x. Magnesium (Mg)

The magnesium ion in water samples was determined using Atomic Absorption method, which describes as follows.

A. Apparatus: AAS wave length at 285.21 nm with 0.7 nm silt.

B. Reagent:

(a) 1000 mg/L standard solution: The solution of magnesium ion was prepared by exactly taking 1.650 g of analytically pure (99%) MgO in a 1000 m/L volumetric flask and added distilled water slowly and shaken well and finally made up to the mark with distilled water slowly well and finally made up to the mark with distilled water.

(b) Suppressing agent: 0.1% Lanthanum solution: The solution of 1% lanthanum (La) was prepared by exactly taken 1 g of lanthanum chloride in a 100 m/L volumetric flask and added of the 1.50 m/L of 1M HC1. Then it was dissolved water and finally, made up to the mark with distilled water gradually and shaken well. 10 m/L of 1% lanthanum was taken and diluted 100 m/L with distilled water to make the final concentrated of 0.15 la. This solution was used for maintained in every standard and sample.

C. Standard curve:

The proportions of 50, 100, 150 and 200 m/L Mg ion contained standard solutions were taken in four different 1000 m/L volumetric flasks and distillated water was gradually added and thoroughly shaken and finally made up to the mark with distilled water. Absorbance of the water samples were determined by AAS. A standard curve was made by plotting the absorbance against the concentration.

D. Calculation:

Magnesium (Mg, mg/L) =

$$(\text{Concentration of Mg from standard curve} \times \text{dilution factor}) \times 1000 \qquad 2.20$$

xi. Iron (Fe)

The iron ion in water samples was determined using Atomic Absorption method, which describes as follows:

A. Apparatus: AAS wave length at 248.3 nm with 0.7 nm silt.

B. Reagent:

1000 mg/L standard solution: The standard solution of calcium ion was prepared by exactly taking 0.250 g of analytically pure (99%) $CaCO_3$ in a 1000 m/L volumetric flask and added distilled water slowly and shaken well and finally made up the mark with distilled water.

C. Standard curve:

The proportions of 0.50, 1, and 2 m/L Fe ion contained standard solutions were taken in three different 1000 m/L volumetric flasks and distillated water was gradually added and thoroughly shaken and finally made up to the mark with distilled water. Absorbance of the water samples were determined by AAS. A standard curve was made by plotting the absorbance against the concentration.

D. Calculation:

Iron (Fe, mg/L) = Concentration of Fe (mg/L)

from standard curve × Dilution factor 2.21

xii. Arsenic (As)

The arsenic ion in water samples was determined using Atomic Absorption method, graphite furnace, which describes as follows:

A. Apparatus: AAS wave length at 193.70 nm with 0.7 nm silt.

B. Reagent:

1000 mg/L standard solution: The standard solution of arsenic ion was prepared by exactly taking 1.3203 g of analytically pure (99%) As_2O_4 in a 1000 m/L volumetric flask and added distilled water slowly and shaken well and finally made up the mark with distilled water.

C. Standard curve:

The proportions of 4, 12, and 20 m/L As ion contained standard solutions were taken in three different 1000 m/L volumetric flasks and distillated water was gradually added and thoroughly shaken and finally made up to the mark with distilled water. Absorbance of the water samples were determined by AAS. A standard curve was made by plotting the absorbance against the concentration.

D. Calculation:

Total inorganic Arsenic (As, mg/L) = Concentration of As, (mg/L)

from Standard curve 2.22

xiii. Faecal Coliform (FC)

The Faecal Coliform (FC) in water samples was determined using membrane Filter procedure, which describes as follows:

A. Apparatus: 200 m/L sample bottle, autoclave, culture dish, graduated membrane filter of 0.45 um pore size and 47 mm diameter, filtration unit, hot plate, incubator, UV-disinfection chamber and Microscope.

B. Reagent: M-FC Agar, rosolic acid, NaOH and ethanol.

C. Procedure:

(a) Preparation of culture medium: The culture media was prepared by exactly taking 51.1 g dehydrated M-FC in a 1000 m/L volumetric flask and added distilled water containing of 10 m/L 1% rosolic acid in 0.2 NaOH slowly and shaken well and finally made up to the mark with distilled water. the solution was heated near to the boiling point to dissolve the medium. Than it was removed from heat and cooled to 50-45°C. About 10 m/L warm medium was dispensed to the sterilized Petri dish.

(b) Sample Preparation: All the Apparatus for this experiment were sterilized by autoclaved. The water sample where collected in a 200 m/L sterilized bottle and kept in refrigerator just after collection. 10 to 100 m/L of water sample was taken in a beaker and diluted to 100 m/L bacteria-free distilled water. Then the sample filtration with 0.45 um pore membrane filter. The filter was removed carefully from filtration unit and placed on the culture media of the petri dish.

(c) Incubation: The petri deshes were placed in the incubator where 44.5±0.2°C temperature was maintained for 24 hours.

(d) Colony counting: To determine colony counts on membrane filters, a low power binocular wide-field dissecting microscope, with a cool white florescent light was used. Colonies produced by faecal coliform bacteria on M.FC Medium were various shades of blue. Non-faecal coliform are grey to cream-color. On M-FC medium very few non-faecal colonies were observed.

D. Calculation:

Number of Faecal Coliform, FC (CFU/100 m/L water) =

Number of colonies on membrane filter × dilution factor 2.23

3.15 Environmental Impact Assessment

Environmental Impact Assessment (EIA) is a formal process to predict the environmental consequences of a development activity and to plan appropriate measures to eliminate or remove adverse effects and to augment positive effects. The three main features of EIA for irrigation from groundwater aquifer are as following-

- To predict problems.
- To find ways to solve the problems
- To enhance environmental friendly irrigation water supply.

The study would identify the problems due to groundwater use for irrigation. The rainfall, groundwater fluctuation data and drawdown curve were used to identify the problem associated to groundwater use for irrigation and conceptualized the impact on environment.

Chapter Four
Results and Discussion

RESULTS AND DISCUSSION

4.1 Yearly variation of groundwater level at five Upazilas of Chapai Nawabganj district

Fluctuation of groundwater level is different in magnitude depending on the extraction and recharge in different locations. In this study groundwater level of Barind area in Chapai Nawabganj district have been analyzed. All available data of Nawabganj, Nachole, Shibganj, Gomastapur and Bholahat Upazilas of Barind area in Chapai Nawabganj district have been considered for preparing hydrographs.

4.1.1 Yearly variation of ground water level

Monthly variations of groundwater level fluctuation of five Upazilas in Chapai Nawabganj District in the Barind area for the year from 2002 to 2011 are shown in Figures 8-12 (Appendix-1). The maximum water table depletion was found between February to May and elevated water tables were found throughout September and October as expected due to post-monsoon groundwater level. The study results also illustrate the maximum water level recorded was about 30 m at Nachole Upazila in 2010 and minimum water level recorded was about 1.0 m at Shibganj Upazila in 2004.

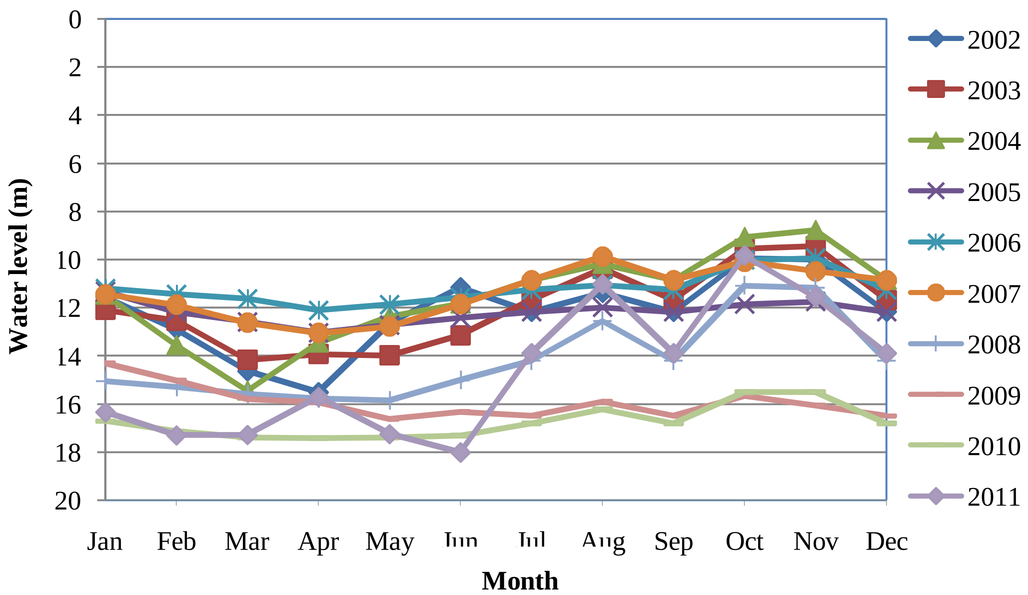

Figure 8 Monthly variation in groundwater level of Nawabganj Upazila for the years 2002-2011.

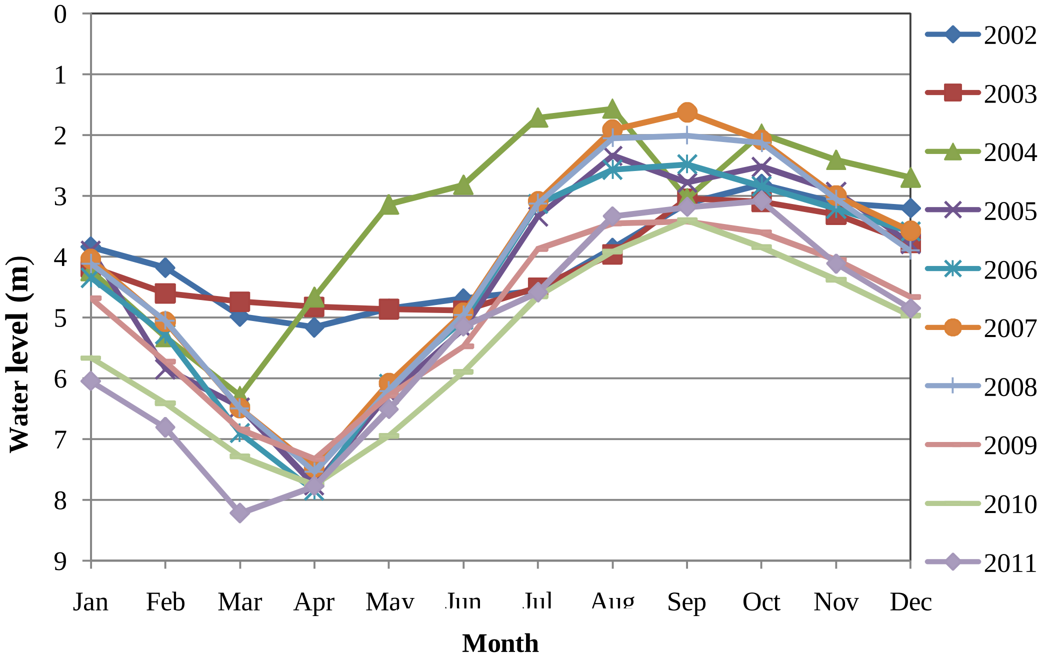

Figure 9 Monthly variation in groundwater level of Shibganj Upazila for the years 2002-2011.

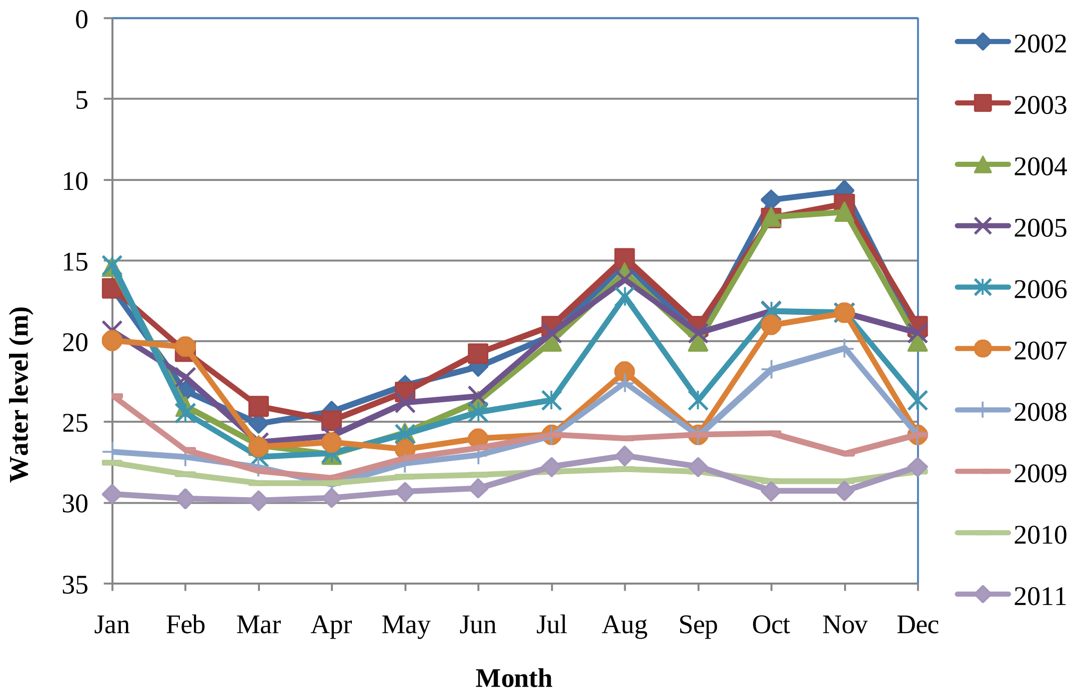

Figure 10 Monthly variation in groundwater level of Nachole Upazila for the years 2002-2011.

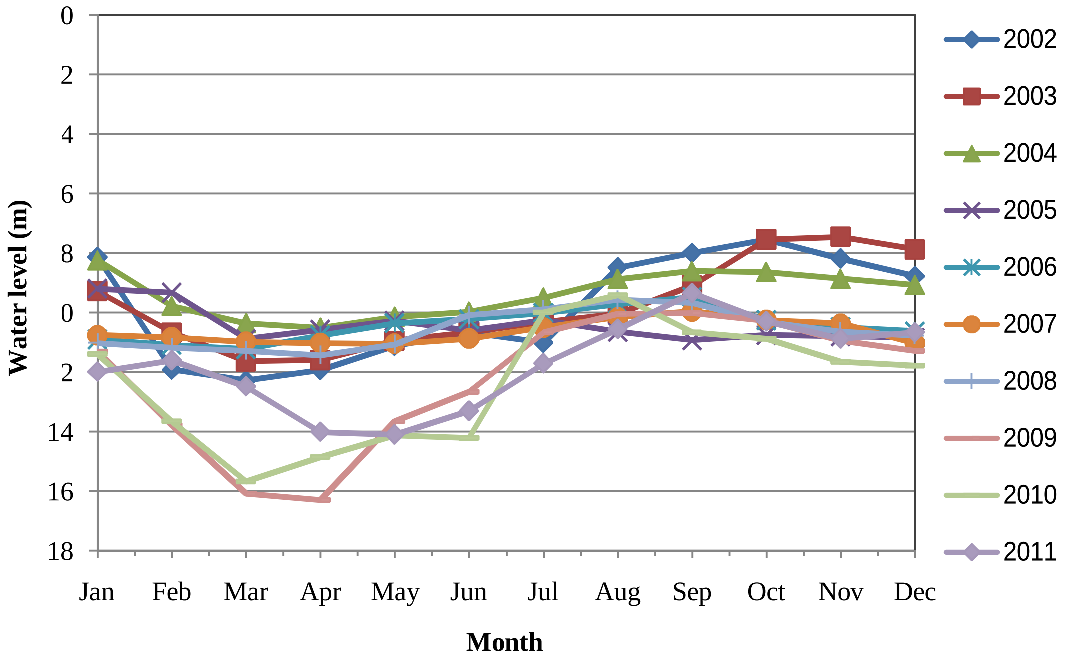

Figure 11 Monthly variation in groundwater level of Gomastapur Upazila for the years 2002-2011.

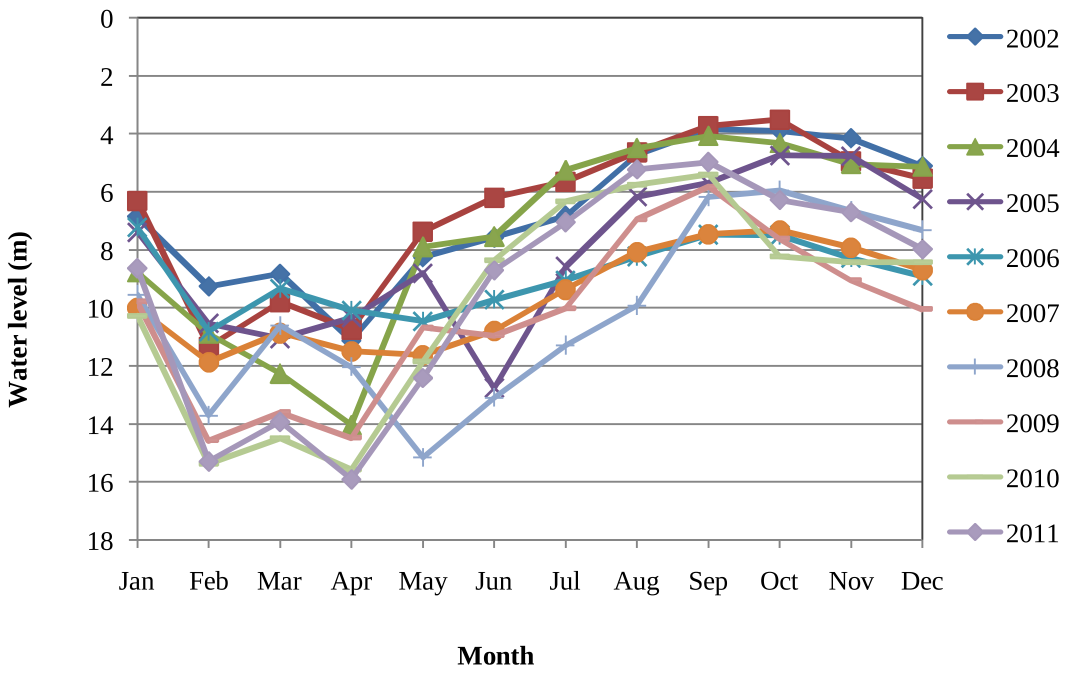

Figure 12 Monthly variation in groundwater level of Bholahat Upazila for the years 2002-2011.

Yearly maximum and minimum groundwater level graphs have been prepared by taking the highest and lowest groundwater table and shown in Figures 13-14. The water level varies from 17.51 m to 8.6 m during 2002-2011 at Nawabganj Upazila. The maximum depletion of water level was found to be 17.51 m in 2010 and minimum was 8.60 m in 2004. In Shibganj Upazila, the water level varies from 8.47 m to 0.9 m. The maximum depletion of groundwater level was found to be 8.47 m in 2011 and the minimum was about 1.0 m 2004. The groundwater level varies from 29.38 m to 9.6 m at Nachole Upazila for the same period was observed. The maximum water level was observed to be 29.5 m in 2010 and the minimum was 10.0 m in 2002. In Gomastapur Upazila, the water level fluctuated from 16.32 m to 7.0 m. The maximum water level was 16.5 m in 2009 and minimum was 7.0 m in 2002. The study also observed groundwater level fluctuation at Bholahat Upazila through the years 2002-2011. The groundwater level varies from 16.0 m to 3.5 m. The maximum water level was observed to be 16.0m in 2011 and minimum was 3.5 m in 2002. Figure 13 shows the maximum groundwater level depletion observed in five Upazilas of Chapai Nawabganj district during the years 2002 to 2011. The results illustrate that the highest groundwater depletion was about 29 m found at Nawabganj Upazila in 2010 and the lowest was about 5m at Shibganj in 2003. Figure 14 shows that the minimum groundwater level depletion of five Upazilas in Chapai Nawabganj district through the years 2002 to 2011. Among the five Upazilas, the highest groundwater depletion was observed in 2011 at Nawabganj and it was about 28 m below the surface and the lowest was about 2 m at Shibganj in 2004.

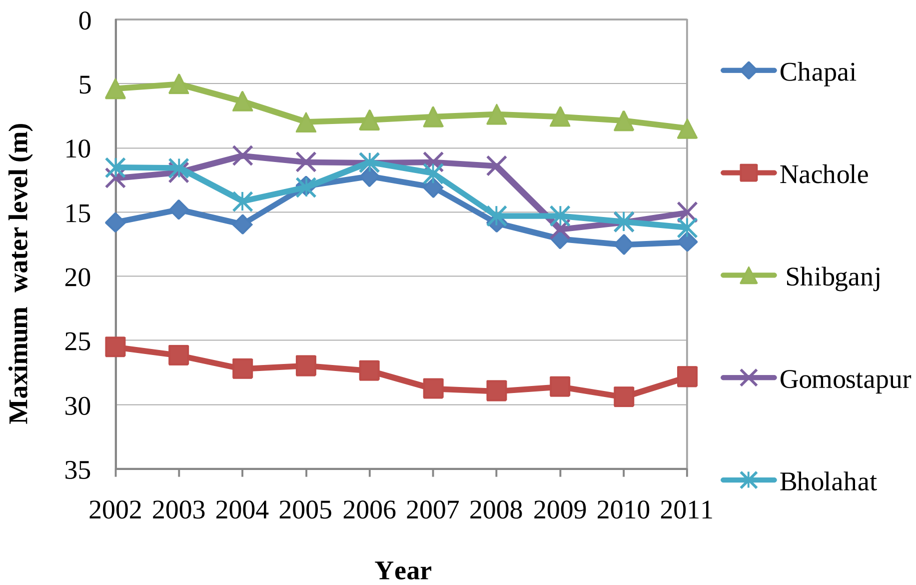

Figure 13 Maximum depletion of groundwater level in five Upazilas of Chapai Nawabganj district from 2002-2011.

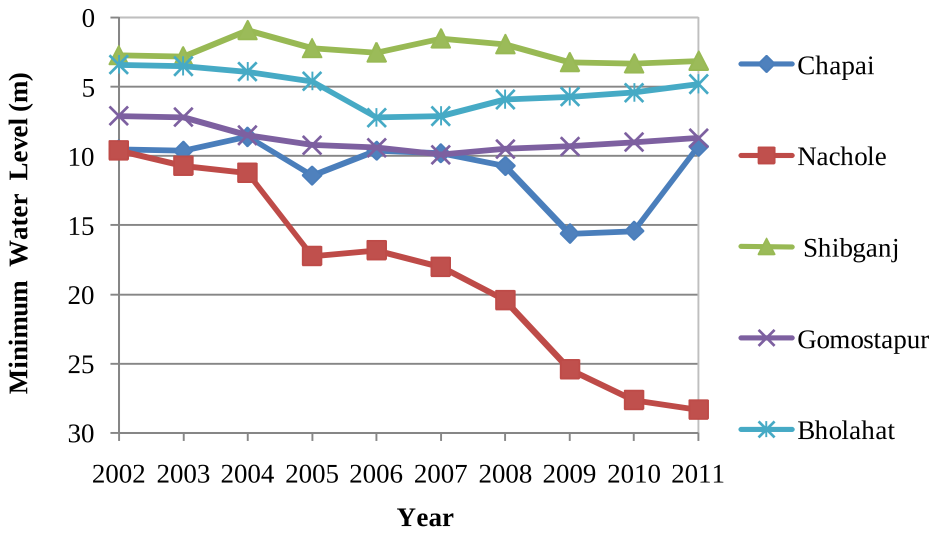

Figure 14 Minimum depletion of groundwater level in five Upazilas of Chapai Nawabganj district through the years 2002-2011.

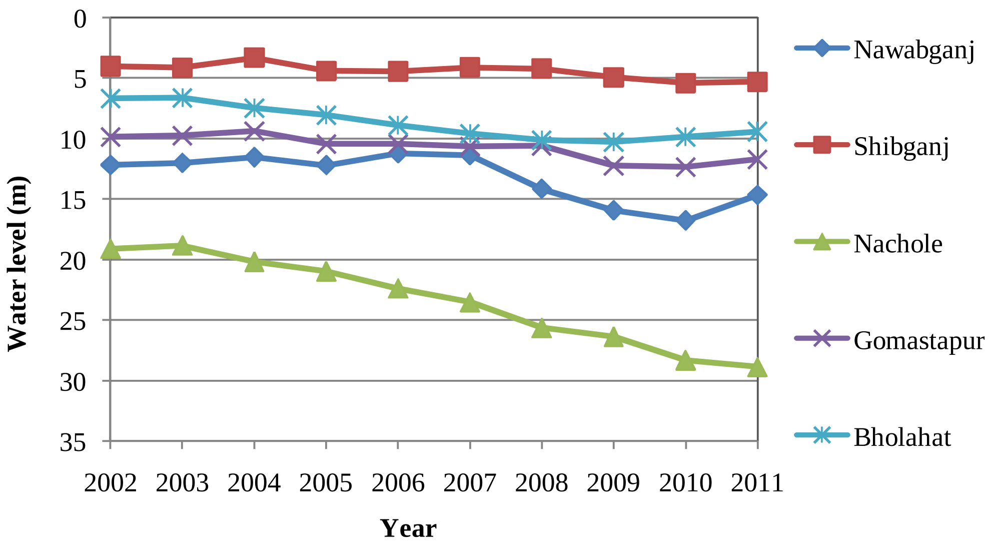

Figure 15 Average groundwater level declined in five Upazilas of Chapai Nawabganj district through the years 2002-2011.

A comparison of depth to water level during 2002 to 2011 reveals that there was a declining trend found in groundwater level in all Upazilas in the study area (Figure 15). The graphs are showing fall of water level in the range of 0-2 m/yr. A slightly fall in water level was observed through 2002 to 2010 in Bholahat, Nawabganj, Shibganj and Gomastapur and rise in water level in 2011 in these areas were more prominent, which is a indication of extremely good rainfall. A comparatively rapid and continuous declined (about 2 m/yr) in water level observed at Nachole Upazila during the study period concerned sustainability of groundwater resource management in the area.

4.2 Rainfall Variation

The monthly rainfall variations in five Upazilas of Chapai Nawabganj district in the Barind area during 2002-2011 are shown in Figures 16-20 (Appendix-2). The maximum rainfall was found throughout June to September during the rainy season of the area. The minimum rainfall was found between February and April and very little or no rainfall occurred during November- January in the study area. The study results illustrate that the maximum rainfall was recorded at Nachole in November 2002, Nachole in July 2003, Bholahat in October 2004, Bholahat in July 2005, Nachole in June 2006, Shibganj in July, 2007, Shibganj in June, 2008, Gomostapur in September, 2009, Gomostapur in June, 2010, and Shibganj in August, 2011.

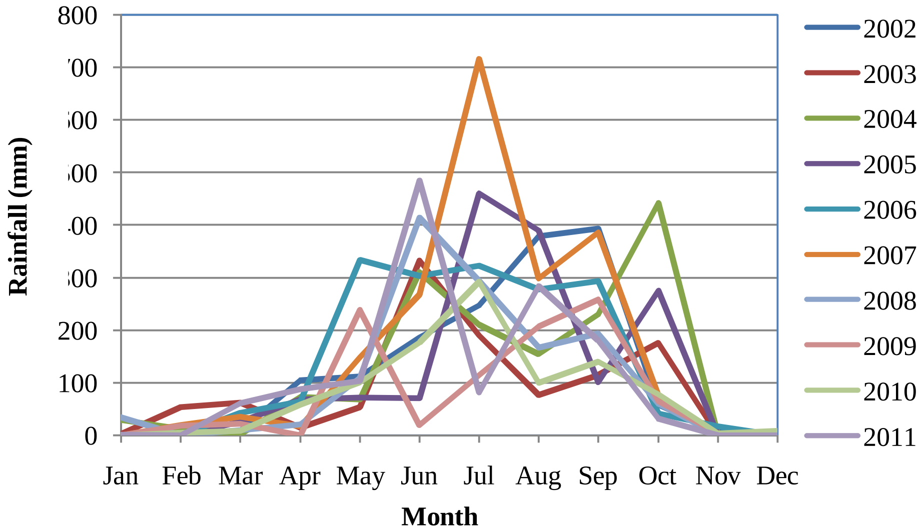

Figure 16 Monthly rainfall variation at Nawabganj Upazila during 2002-2011.

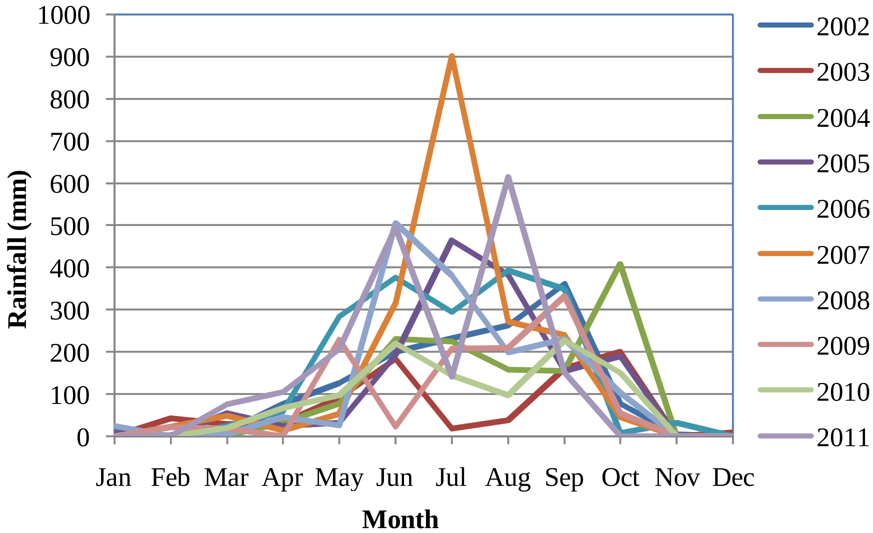

Figure 17 Monthly rainfall variation at Shibganj Upazila during 2002-2011.

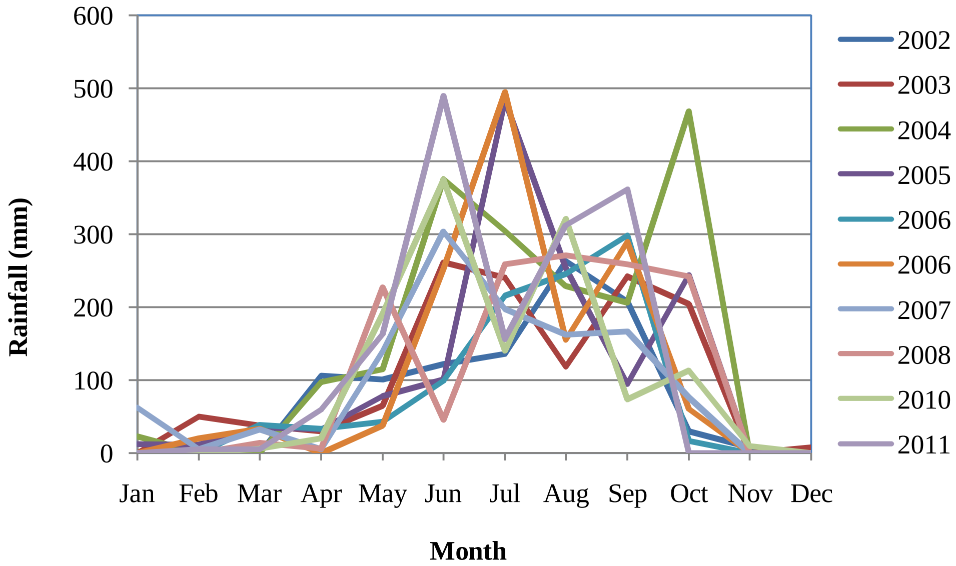

Figure 18 Monthly rainfall variation at Gomastapur Upazila during 2002-2011.

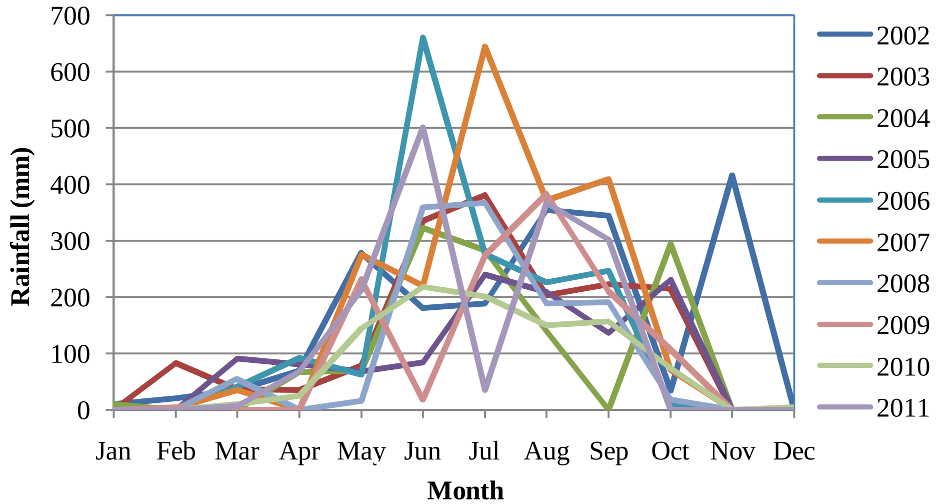

Figure 19 Monthly rainfall variation at Nachole Upazila during 2002-2011.

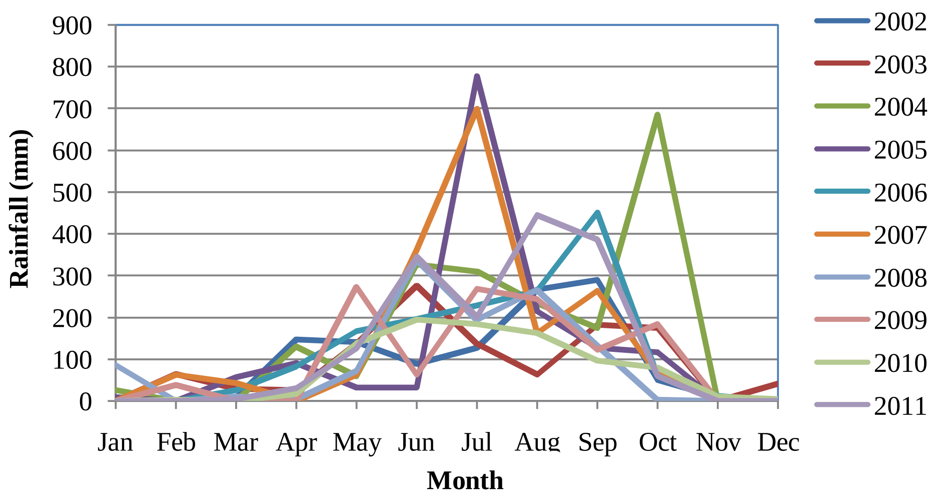

Figure 20 Monthly rainfall variation at Bholahat Upazila during 2002-2011.

Table 7

Annual rainfall of five Upazilas in Chapai Nawabganj district during 2002-2011

Year	Nawabganj (mm)	Shibganj (mm)	Gomostapur (mm)	Nachole (mm)	Bholahat (mm)	Chapai Nawabganj District (mm)
2002	1503	1503	974	1932	1131	1408
2003	1082	1082	1256	1592	1137	1230
2004	1529	1529	1817	1187	1945	1601
2005	1461	1461	1344	1141	1459	1373
2006	1695	1695	990	1616	1488	1497
2007	1964	1964	1341	2029	1722	1804
2008	1302	1302	1147	1195	1101	1209
2009	946	946	1324	1228	1200	1129
2010	971	971	1248	987	897	1015
2011	1314	1314	1551	1496	1598	1454

The maximum annual rainfall recorded was 1804 mm in 2007. Since then, rainfall was gradually decreasing for consecutive three years, but it was increased 439 mm in 2011 from 1015 mm recorded in the previous year. The results show that Nachole Upazila received the highest rainfall 2029 mm in 2007 and Bholahat Upazila received the lowest rainfall 897 mm in 2010 during the study period of the area. The average rainfall received in Chapai Nawabganj district was 1372 mm during 2002-2011 (not shown in the table 7). A report showed that the rainfall recorded was about 1738 mm in 1981 and 798 mm in 1992 in the Baring area suggesting yearly rainfall variations (Banglapedia Website). The rainfall data of the study also show a wide variation of rainfall depending on area and year.

4.3 Estimated Run-off and Infiltration

The rainfall runoff and infiltration processes are well described in the literature (Gomez, *et al*., 2001; Holden, *et al*., 2002; Rawls, *et al*., 1982; Yu, *et al*., 1997; Janeau, *et al*., 1999; Paige, *et al*., 2003). Numerous papers on the subject have been published and many computer simulation models have been developed. All these models, however, require detailed knowledge of a number of factors and initial boundary conditions in a catchment area which in most cases are not readily available. The infiltration capacity of the soil depends on its texture and structure, as well as on the antecedent soil moisture content (previous rainfall or dry season). The initial capacity (of a dry soil) is high but, as the storm continues, it decreases until it reaches a steady value termed as final infiltration rate. Runoff is generated by rainstorms and its occurrence and quantity are dependent on the characteristics of the rainfall event, i.e. intensity, duration and distribution. However, rather simple equations of runoff and infiltration were used to predict the amount of runoff and infiltration resulting from rainfall events and understand the effect of rainfall on groundwater level fluctuation.

The runoff was estimated from the rainfall and the results show the maximum estimated runoff was 304 mm found in 2007 at Nachole Upazila and the minimum was 121 mm in 2003 at Shibganj Upazila during the study period (Table 8). Without any exception, runoff was gradually decreasing in the study area for consecutive three years since 2007, but it was increased in all Upazilas of the district in 2011 as expected due to higher rainfall received this year.

Table 8

Estimated runoff of five Upazilas in Chapai Nawabganj district during 2002-2011.

Year	Nawabganj (mm)	Shibganj (mm)	Gomostapur (mm)	Nachole (mm)	Bholahat (mm)
2002	225	204	146	289	169
2003	162	121	188	238	170
2004	229	194	272	178	291
2005	219	225	201	171	218
2006	254	273	148	242	223
2007	294	286	201	304	258
2008	195	228	172	179	165
2009	141	164	198	184	179
2010	145	153	187	148	134
2011	197	268	232	224	239

The infiltration of the study area was calculated using evapotranpiration (ET) data (Appendix-3). The estimated infiltration results of Chapai Nawabganj district illustrate that the highest infiltration was 1700 mm found in 2007 at Nachole Upazila and the minimum was 657 mm found in 2003 at Shibganj Upazila (Table 9). In the study area, a decreasing trend in infiltration was observed for consecutive three years in the study since 2007, but it was increased in 2011 in all Upazilas due to higher rainfall received this year. An overall fluctuation was observed in estimated infiltration throughout the study period.

Table 9

Estimated infiltration of five Upazilas in Chapai Nawabganj district during 2002-2011

Year	Nawabganj (mm)	Shibganj (mm)	Gomostapur (mm)	Nachole (mm)	Bholahat (mm)
2002	1245	1129	803	1610	934
2003	888	657	1037	1323	936
2004	1272	1076	1520	988	1630
2005	1217	1248	1113	945	1214
2006	1414	1521	817	1350	1239
2007	1643	1597	1113	1700	1439
2008	1079	1268	946	993	909
2009	778	909	1099	1021	995
2010	793	844	1033	811	733
2011	1090	1498	1293	1248	1332

4.4 Annual rainfall and Relation with Run-off and Infiltration.

The amount of runoff and infiltration were varied with rainfall received as expected. The highest annual rainfall received was 1793 mm in 2007 and the lowest was 1025 mm in 2010 in the district (Table 10). The results show a good relation among the parameters indicating that the higher amount was the rainfall, the higher amounts were the estimated runoff and infiltration. This observation was supported by previous reports (Gomez, *et al*., 2001; Holden, *et al*., 2002; Paige, *et al*., 2003)

Table 10

Annual rainfall, runoff and infiltration of Chapai Nawabganj District during 2002-2011

Year	Rainfall (mm)	Runoff (mm)	Infiltration (mm)
2002	1380	207	1144
2003	1175	176	968
2004	1554	233	1297
2005	1381	207	1147
2006	1521	228	1268
2007	1793	269	1498
2008	1253	188	1039
2009	1159	173	960
2010	1025	153	843
2011	1549	232	1292

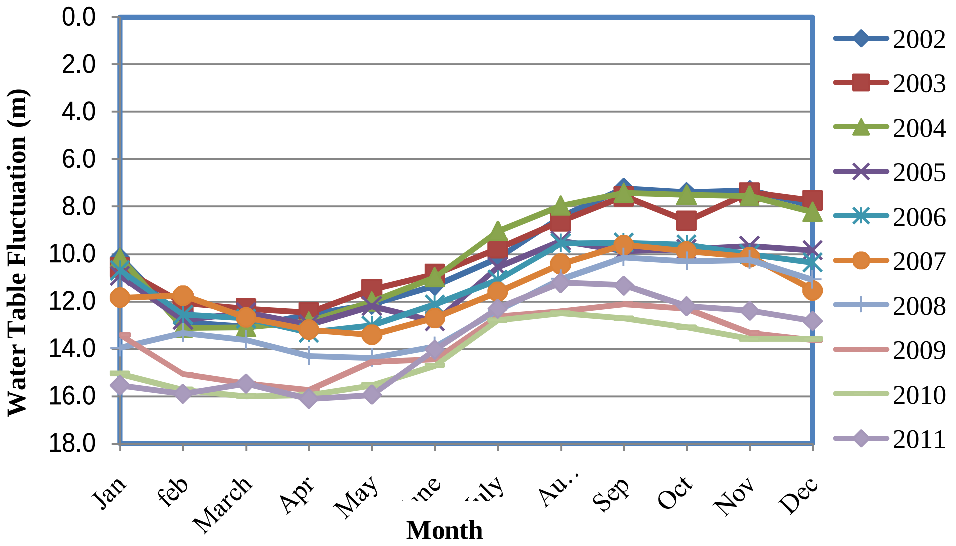

Figure 21 Monthly water table fluctuation of Chapai Nawabganj district for the years 2002-2011.

The figure shows a good trend of water table fluctuations of Chapai Nawabganj district in the Barind area during 2002 to 2011 (Figure 21). The results illustrate that the overall water table level showed minimum in 2004 and maximum in 2011. The graphs show wave like fluctuation curves, where the highest depletion occurred during March-April and then the water table moved upward direction slowly and reached at minimum level during September-October and again slowly depleted until rain started in May. The study results reveal that a good relation between rainfall and water table fluctuations was observed where the groundwater table was recharged by the rainfall. The overall yearly water table declining trend indicate that unsustainable withdrawal of groundwater for irrigation and domestic purposes would be played a vital role in water table fluctuations in the study area.

4.5 Boring Log soil formation of Chapai Nawabganj district.

Barind Tract is an uplifted block occurs as horst along pre-existing line of crustal weakness. Clay thickness varies from 4m in the southwest to over 35 m in north-west (BMDA, 2006). Elevation of the area varies from 9 m to 47 m PWD (Public Works Department). The boreholes were drilled in 2013 by Barind Multipurpose Development Authority (BMDA) and collected soil samples from the site .Available log data from these boreholes were about 38 m to 58.00 m from the ground surface in the study area.

Upazila		**Union**	**Mouza**		**JL No**	**Plot No**
Nawabganj		**Jhilim**	**Chattigran**		**83**	**277**
Drilling time log		Graphic log	Thickness (m)		Description of formation	
from	to		from	to		
20/09/13 at 12.00 Noon			0.0		Clay	
				21.35		
			21.35		Find Sand	
				36.60		
			36.60		Medium to Coarse Sand	
	21/09/13 at 10.00 am					
				44.00		
			44.00		Silt Clay	
				49.00		
			49.00		Medium to Coarse Sand	
				54.00		
			54.00			
					Stone	
				58.00		

Figure 22 Boring Log Data for Nawabganj Upazila.

The different types of soil formation of five Upazilas in Chapai Nawabganj district are shown in Figures 22-26. All the five boreholes log are very similar and the Figures illustrate that a stone layer at the bottom of the bore log and above this unit, sediments consisting of coarse sand, silt clay, medium to coarse sand, fine sand and finally clay made up with various additional confining units.

Upazila		**Union**	**Mouza**		**JL No**	**Plot No**
Shibganj		**Pethalitala**	**Bhusamara**		**31**	**954**
Drilling time log		Graphic log	Thickness (m)		Description of formation	
from	to		from	to		
15-02-13 at 10.00 am			0	6.10	Hard Clay	
			6.10	18.30	Sandy Clay	
			18.30	30.50	Medium to Coarse Sand (Gray)	
	15-02-13 at 8.00 am		30.50	45.00	Coarse Sand (Gray) With Stone	
			45.00	50.00	Stone	

Figure 23 Boring Log Data for Shibganj Upazila.

Highest thickness of clay layer 27.45 m was found in Chapai Nawabganj district at Nachole Upazila (Figure 24) and lowest thickness of hard clay layer 12.20 m was found at the at Bholahat Upazila (Figure 25).Thickness of clay layer was 21.35 m, fine sand found from 21.35 m to 36.60 m below the surface medium to coarse sand and silt clay found 36.60 m to 44.00 m and 44.00 m to 49.00 m respectively medium to coarse sand appears from 49.00 m to 54 m (Figure 22).

Upazila		**Union**	**Mouza**		**JL No**	**Plot No**
Nachole		**Fatepur**	**Takahara**		**88**	**572**
Drilling time log		Graphic log	Thickness (m)		Description of formation	
from	to		from	to		
30-01-13 at 12.00 am			0	27.45	Clay (Brown)	
	31-01-13 at 08.00 am		27.45	29.00	Fine Sand (Brown)	
			29.00	37.00	Medium sand (Gray)	
			37.00	38.00	Stone	

Figure 24 Boring Log Data for Nachole Upazila.

Figure 22 -26 show that the thickness of the clay layer is highest at Nachole Upazila borehole and it was about 27.45 m and below the depth from the ground sand aquifer found with appearance of brown and gray colored medium sand. After drilling of 57.00 m from the ground stone appeared in the area. About five borehole log data of five Upazilas of Chapai Nawabganj district are analyzed and the average thickness was found 19.52 m.

Upazila		**Union**	**Mouza**		**JL No**	**Plot No**
Gomastapur		**Boalia**	**Kalinagar**		**133**	**248**
Drilling time log		Graphic log	Thickness (m)		Description of formation	
from	to		from	to		
13-02-13 at 12.00 am			0		Flexi alluvial Clay	
				18.30		
			18.30		Fine to Medium Sand (Light Gray)	
				30.50		
	14-02-15 at 10.00 am		30.50		Medium Coarse sand (Gray)	
				42.70		
			42.70		Coarse sand (Gray)	
				48.00		
			48.00		Stone	
				48.00		

Figure 25 Boring Log Data for Gomastapur Upazila.

Clay becomes sticky and clumpy when wet. It also has fine particles, only visible with a microscope. Clay soil tends to have poor drainage and it is slow to warm up. It is difficult to plant in clay soil since it hardens to a consistency nearly as hard as concrete which is very low permeability and can pass a little amount infiltration. The permeability of the clay is very low and it is termed as aquitard (BMDA 2006).

Upazila		**Union**	**Mouza**		**JL No**	**Plot No**
Bholahat		**Gohalbari**	**Gohalbari**		**21**	**7263**
Drilling time log		Graphic log	Thickness (m)		Description of Formation	
from	to		from	to		
22-01-13 at 10.00 am			0	12.20	Hard Clay	
			12.20	24.40	Find to Medium sand (Gray)	
			24.40	30.50	Medium sand (Gray)	
	23-01-13 at 08.00 am		30.50	42.00	Silt Clay	
			42.00	48.00	Stone	

Figure 26 Boring Log Data for Bholahat Upazila.

4.6 Determination of specific yield

Copper-Jacob method of solution of pumping test data was obtained using the programming software Math lab (Appendix-4). Drawdown was plotted as a function of time in semi-logarithmic paper. Specific yield coefficient (Δs) of Nawabganj Upazila was estimated from the gradient of the straight line (Figure 27) and the value was 0.983606. The extended line to where it crossed the x axis that is called zero drawdown (t_o) and the value was 5.8. Similarly, specific yield coefficient of other Upazilas, namely Shibganj, Nachole, Bholahat and Gomastapur were 0.993, 0.996, 0.997 and 0.997, respectively and t_o were 8.0, 8.20, 7.00 and 7.00 min., respectively (Figures 28-31).

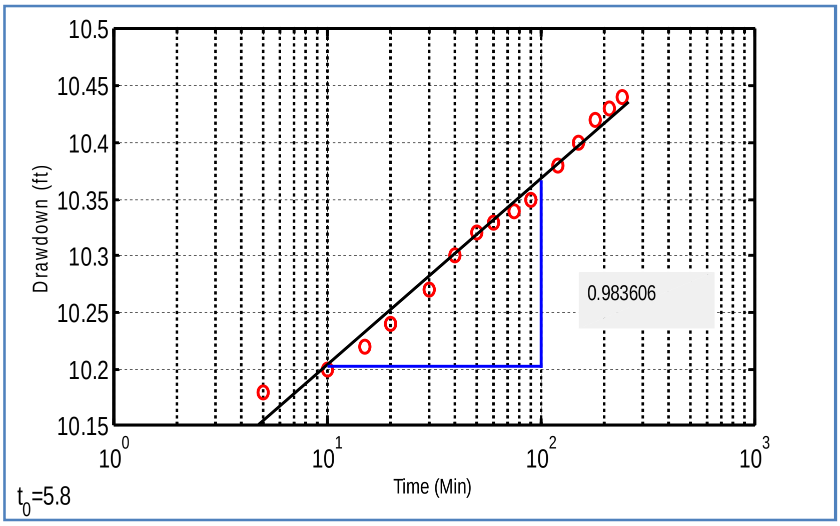

Figure 27 Copper-Jacob method of solution of pumping test data for Nawabganj Upazila.

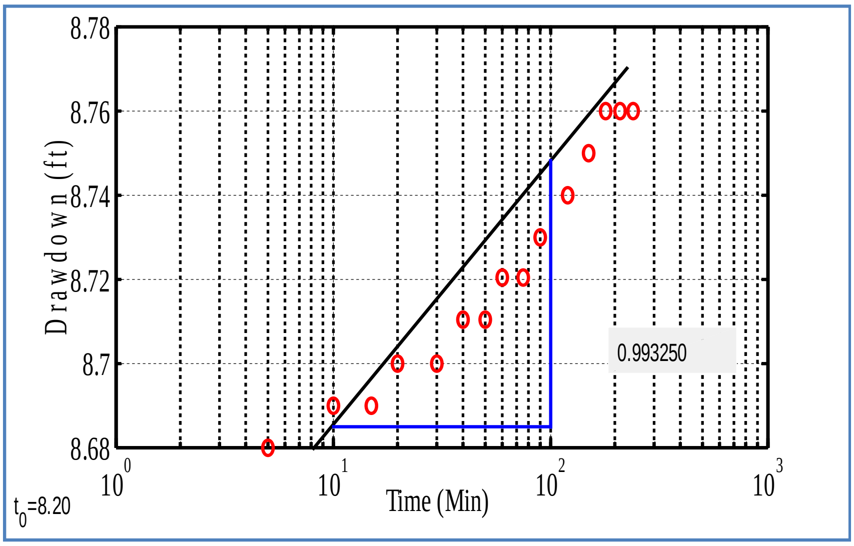

Figure 28 Copper-Jacob method of solution of pumping test data for Shibganj Upazila.

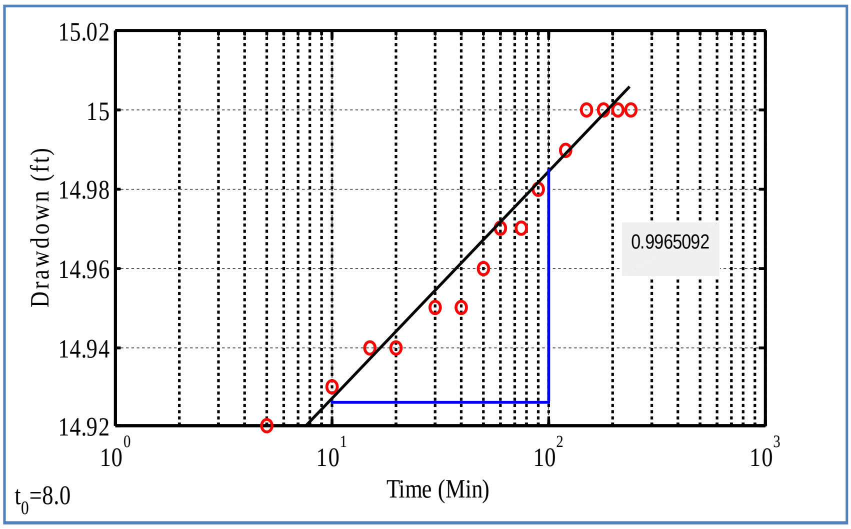

Figure 29 Copper-Jacob method of solution of pumping test data for Nachole Upazila.

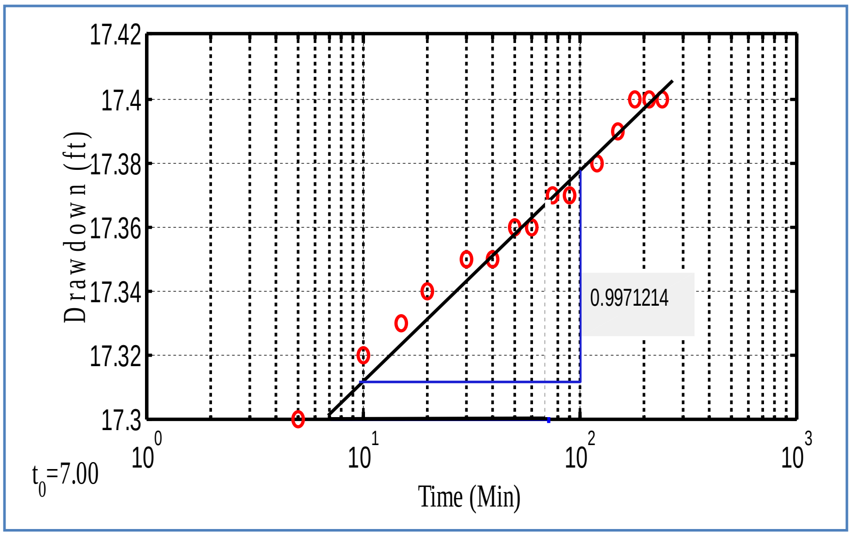

Figure 30 Copper-Jacob method of solution of pumping test data for Gomastapur Upazila.

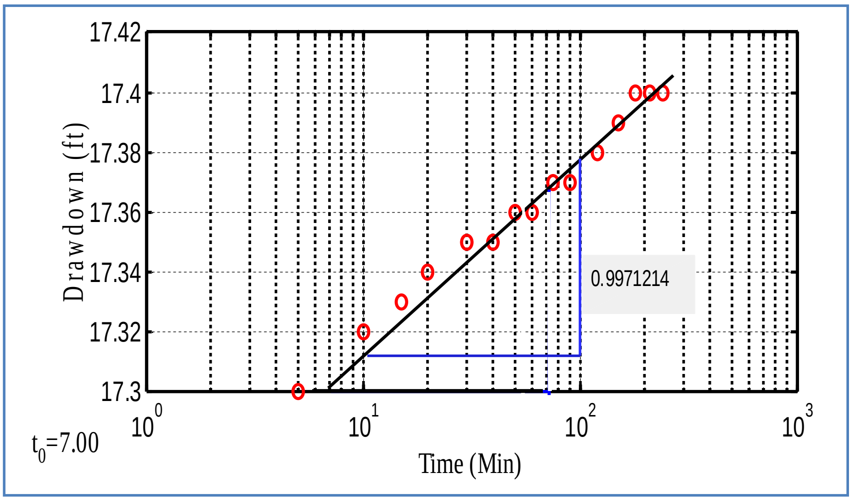

Figure 31 Copper-Jacob method of solution of pumping test data for Bholahat Upazila.

Table 11

Determination of specific yield of five Upazilas of Chapai Nawabganj District

Upazila	Discharge Q (ft^3/min)	Drawdown difference per log cycle ΔS (ft)	Radius of influence r_e (ft)	Zero Drawdown t_0 (min)	Transmissivity $T = \frac{2.3Q}{4\pi\Delta S}$ (ft^2/min)	Specific Yield $Sy = \frac{2.25Tt}{r^2}$ (%)
Nawabganj	120	0.983	30.68	5.8	22.34	9.5
Shibganj	120	0.993	40.41	8.20	22.12	10.1
Nachole	120	0.996	38.53	8.0	22.05	10.3
Gomastapur	120	0.997	34.02	7	22.03	10.2
Bholahat	120	0.997	41.31	7.00	22.03	8.4

Specific yield of the five Upazilas were determined using the equation mentioned in Table 11 and the values were found around 10 (%) which indicate good permeability of the areas, except Bholahat Upazila, where the value was 8.4 (%) indicating low permeability.

4.6.1 Groundwater storage of five Upazilas in Chapai Nawabganj District.

Groundwater is water located below the ground surface in soil pore spaces and rock fractures. In nature, surface water and groundwater are intimately connected via the water cycle. Surface water, flowing or stagnant, percolates downward through the soil and becomes part of the groundwater table.

The storage capacity of the five Upazilas in Chapai Nawabganj district in the Barind area was estimated using the area, the average fluctuation and specific yield storage of groundwater and the results illustrate that Nachole Upazila has comparatively a large storage volume, i.e., 49,305 ha-m, but the other Upazilas have a storage capacity between 8000 to 18000 ha-m (Table 12). The storage capacity of the five Upazilas were followed the order: Nachole>Nawabganj>Shibganj>Gomastapur>Bholahat.

Table 12

Estimated storage of groundwater of five Upazilas of Chapai Nawabganj District

SL No.	Upazila	Specific yield S_y	Area (ha.) *a*	Average fluctuation of G.W. (m) *f*	Storage of G.W. (ha-m) $Sy \times a \times f$
1	Nawabganj	.095	45178	4.3	18455.21
2	Shibganj	.101	31813	4.7	15101.63
3	Nachole	.102	52542	9.2	49305.41
4	Gomastapur	.103	28367	3.9	11395.02
5	Bholahat	.084	12353	8.4	8716.277
Total Storage of groundwater					**102973.6**

4.6.2 Groundwater withdrawing at five Upazilas of Chapai Nawabganj District per year.

A total of 43 deep tubewells (DTWs) at the rate of 2 cusec capacity were operated for 800 hours/year at Nawabganj Upazila and the extraction of groundwater/year of the Upazila was 3471 ha-m (Table 13). The highest number of DTWs was installed at Nachole Upazila and the extracted amount was 8848 ha-m indicating excessive extraction concerned sustainable water management.

Table 13

Volume of water extracted per year in five Upazilas of Chapai Nawabganj District

SL. No.	Name of Upazila	DTWs	Vol^m water Extracted. (ha-m)	Total Vol^m extracted. (ha-m)
1	Nawabganj	43	3471	
2	Shibganj	243	3960	
3	Nachole	543	8848	26822
4	Gomostapur	401	6534	
5	Bholahat	246	4009	

4.7 Seasonal variation of physico-chemical and microbial parameters of Groundwater

A total of 50 DTWs water samples were collected twice, i.e., March and October in 2014 from five locations of each Upazila of Chapai Nawabganj district in the Barind area and analyzed for physico-chemical parameters.

4.7.1 Variation in physical parameters in groundwater

i. Temperature

The highest temperature of DTWs was found to be 28.45 and 26.5°C in March (pre-monsoon), and October (post-monsoon), respectively in the study area. The lowest was 27.8°C and 25.8°C in March (pre-monsoon), and October (post-monsoon) 2014, respectively (Table 14-23). The result indicate that the groundwater temperature was slightly varies with seasonal temperature. Jinwal and Dixit (2008) supported the present finding where the groundwater temperature recorded in pre-monsoon in Bhopal India was higher than the post-monsoon.

Table 14

Physico-chemical characteristics of groundwater of Nawabganj Upazila in March, 2014

Parameters	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4	Sample No. 5	Mean±SD
	Jhilem (Plot-1183)	Amnura (Plot-62)	Jhilem (Plot-1183)	Vabuk (Plot-288)	Jhilim (Plot-747)	
Temperature	28.13	28.45	27.9	28.2	28.1	27.9±0.199
pH	7.9	8.0	8.1	8.2	7.9	7.9±0.130
EC (µS/cm)	704	458	7525	784	710	458±3070.789
TDS (mg/L)	355	375	394	400	375	355±17.824
TH	125	120	130	122	120	120±4.219
Cl^- (mg/L)	42.2	41.0	45.2	38.1	32.8	32.8±4.697
SO_4^{2-}(mg/L)	6.52	6.6	5.9	5.8	6.3	5.8±0.36
HCO_3^-	310	342	325	382	354	310±27.637
Na(mg/L)	22.9	43.62	35.52	39.5	29.25	22.9±8.227
K (mg/L)	3.5	5.1	4.2	3.8	4.1	3.5±0.602
Ca (mg/L)	55.2	51.3	57.5	58.3	55.3	51.3±2.721
Mg (mg/L)	12.76	8.7	9.2	6.2	7.6	6.2±2.450
Fe(mg/L)	0.041	0.065	0.072	0.034	0.092	0.034±0.42
As(mg/L)	0	0	0	0	0	0
FC	0	0	0	0	0	0

Unit: All unit area in mg/L except Temperature in, EC in µS/cm and pH

Table 15

Physico-chemical characteristics of groundwater of Shibganj Upazila in March, 2014

Parameters	Sample No. 1 Chakla (Plot-1059)	Sample No. 2 Ekhlaspur (Plot-528)	Sample No. 3 Chalkdilalp (Plot-19)	Sample No. 4 Birahimpur (Plot-311)	Sample No. 5 Lahapur (Plot-105)	Mean±SD
Temperature	27.8	28.0	28.3	28.2	28.3	27.8±0.217
pH	7.7	7.9	7.7	7.8	7.5	7.5±0.148
EC (µS/cm)	670	589	695	755	790	589±78.056
TDS (mg/L)	455	480	495	435	560	435±47.828
TH	455	405	420	520	350	350±62.948
Cl^- (mg/L)	41.2	42.5	40.5	58.5	46.5	40.5±7.448
SO_4^{2-}(mg/L)	9.8	4.9	5.8	8.9	7.8	4.1±2.06
HCO_3^-	493	501	566	454	401	401±60.988
Na(mg/L)	27.55	43.62	40.25	38.1	32.2	27.55±6.438
K (mg/L)	7.0	7.5	7.1	7.6	7.2	7±0.259
Ca (mg/L)	62.9	57.98	50.88	57.6	49.5	49.5±5.529
Mg (mg/L)	8.77	9.5	10.25	10.11	9.1	8.77±0.639
Fe(mg/L)	0.09	0.038	0.04	0.05	0.12	0.038±0.036
As(mg/L)	0	0	0	0	0	0
FC	0	0	0	0	0	0

Unit: All unit area in mg/L except Temperature in, EC in µS/cm and pH

Table 16

Physico-chemical characteristics of groundwater of Nachole Upazila in March, 2014

Parameters	Sample No. 1 Gonoir (Plot-120)	Sample No. 2 Pos. Mirzapur (Plot-125)	Sample No. 3 Sreerampur (Plot-70)	Sample No. 4 Khandura (Plot-134)	Sample No. 5 Sobdolpur (Plot-318)	Mean±SD
Temperature	28.0	28.1	28.1	27.9	28.1	27.9±0.089
pH	7.6	7.5	7.6	7.5	7.5	7.5±0.055
EC (µS/cm)	745	810	805	750	710	710±42.632
TDS(mg/L)	370	385	295	370	293	293±44.792
TH	102	121	129	122	119	102±10.015
Cl^- (mg/L)	9.5	12.5	10.05	14.05	15.8	9.5±2.656
SO_4^{2-}(mg/L)	16.8	11.2	9.7	8.72	9.4	9.4±33.862
HCO_3^-	301	411	368	402	455	413±57.405
Na(mg/L)	27.5	22.8	45.92	31.8	36.5	22.8±8.872
K (mg/L)	3.72	3.02	4.4	6.2	4.95	3.02±1.214
Ca (mg/L)	35.24	51.9	53.18	49.7	43.57	35.24±7.402
Mg (mg/L)	7.9	4.5	6.1	9.02	9.2	4.5±2.012
Fe(mg/L)	0.06	0.033	0.08	0.10	0.17	0.033±0.052
As(mg/L)	0	0.003	0	0	0	0±0.001
FC	0	0	0	0	0	0

Unit: All unit area in mg/L except Temperature in, EC in µS/cm and pH

Table 17

Physico-chemical characteristics of groundwater of Gomastapur Upazila in March, 2014

Parameters	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4	Sample No. 5	Mean±SD
	Akkelpur (Plot-709)	Chalkvobani (Plot-218)	Gorbari (Plot-341)	Khoirabad (Plot-1163)	Bosonitola (Plot-436)	
Temperature	28.3	28.1	28.3	28.1	28.2	28.1±0.100
pH	7.6	7.5	7.5	7.6	7.8	7.5±0.122
EC (µS/cm)	810	825	930	755	800	755±64.750
TDS(mg/L)	543	375	541	463	403	375±77.149
TH	85	199	101	103	107	85±45.497
Cl^- (mg/L)	34.8	60.8	67.4	67.6	20.9	20.9±21.252
SO_4^{2-}(mg/L)	16.29	16.5	11.0	13.6	15.9	11±2.350
HCO_3^-	455	325	410	402	355	325±50.54
Na(mg/L)	41.4	20.5	25.5	35.3	37.1	20.5±8.657
K (mg/L)	6.2	7.43	6.25	5.9	7.25	5.9±0.686
Ca (mg/L)	37.5	39.3	36.52	43.89	47.0	36.52±4.456
Mg (mg/L)	5.7	4.6	5.1	5.4	5.5	4.6±0.428
Fe(mg/L)	0.052	0.8	0.24	0.88	0.78	0.052±0.377
As(mg/L)	0	0.003	0	0	0	0±0.001
FC	0	0	0	0	0	0

Unit: All unit area in mg/L except Temperature in, EC in µS/cm and pH

Table 18

Physico-chemical characteristics of groundwater of Bholahat Upazila in March, 2014

Parameters	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4	Sample No. 5	Mean±SD
	Borojambaria (Plot-904)	Helachi (Plot-334)	Modhupur (Plot-2123)	Modhupur (Plot-655)	Khalealompur (Plot-508)	
Temperature	28.1	28.0	28.3	28.2	26.12	26.12±0.915
pH	7.5	7.5	7.8	7.7	7.3	7.3±0.195
EC (µS/cm)	901	850	954	825	823	823±56.234
TDS(mg/L)	535	474	542	502	513	474±27.234
TH	120	115	102	155	92	92±24.015
Cl^- (mg/L)	71.6	34.5	33.59	20.9	13.5	13.5±22.376
SO_4^{2-}(mg/L)	5.5	12.5	10.2	8.1	8.3	5.5±2.608
HCO_3^-	475	411	450	411	456	411±28.553
Na(mg/L)	29.72	29.6	28.5	27.4	28.5	27.4±0.95
K (mg/L)	4.69	3.75	4.51	4.25	4.0	3.75±0.379
Ca (mg/L)	62.3	46.5	51.9	69.9	39.09	39.09±12.295
Mg (mg/L)	10.6	3.56	5.42	5.9	4.1	3.56±2.785
Fe(mg/L)	0.002	0.025	0.04	0.078	0.05	0.02±0.209
As(mg/L)	0	0.0	0	0	0	0
FC	0	0	0	0	0	0

Unit: All unit area in mg/L except Temperature in, EC in µS/cm and pH

Table 19

Physico-chemical characteristics of groundwater of Nawabganj Upazila in October, 2014

Parameters	Sample No. 1 Jhilem (Plot-1183)	Sample No. 2 Amnura (Plot-62)	Sample No. 3 Jhilem (Plot-1183)	Sample No. 4 Vabuk (Plot-288)	Sample No. 5 Jhilim (Plot-747)	Mean±SD
Temperature	26.3	26.5	26.0	26.4	26.3	26±0.187
pH	7.9	7.8	7.7	7.7	7.5	7.5±0.148
EC (µS/cm)	804	778	825	844	790	778±26.574
TDS (mg/L)	360	380	394	405	386	360±16.823
TH	192	166	179	174	168	166±10.402
Cl^- (mg/L)	40.2	40.2	43.5	36.8	33.5	33.5±3.811
SO_4^{2-}(mg/L)	6.5	6.5	6.4	6.3	6.1	6.1±0.167
HCO_3^-	347	342	357	390	364	342±18.828
Na(mg/L)	22.99	43.68	35.5	39.7	29.8	22.99±8.166
K (mg/L)	3.52	5.08	4.1	3.88	4.5	3.25±0.6
Ca (mg/L)	54.45	50.62	56.38	58.30	54.46	50.62±2.848
Mg (mg/L)	13.76	9.96	9.25	6.87	7.82	6.87±2.653
Fe(mg/L)	0.043	0.068	0.078	0.034	0.092	0.034±0.419
As(mg/L)	0	0	0	0	0	0
FC	0	0	0	0	0	0

Unit: All unit area in mg/L except Temperature in, EC in µS/cm and pH

Table 20

Physico-chemical characteristics of groundwater of Shibganj Upazila in October, 2014

Parameters	Sample No. 1 Chakla (Plot-1059)	Sample No. 2 Ekhlaspur (Plot-528)	Sample No. 3 Chalkdilalp (Plot-19)	Sample No. 4 Birahimpur (Plot-311)	Sample No. 5 Lahapur (Plot-105)	Mean±SD
Temperature	26.1	26.1	26.5	26.4	26.2	26.1±0.182
pH	7.3	7.5	7.5	7.4	7.1	7.1±0.167
EC (µS/cm)	754	703	810	855	870	703±69.888
TDS (mg/L)	470	490	505	550	570	470±41.773
TH	565	497	510	629	459	459±66.212
Cl^- (mg/L)	40.2	43.5	40.2	60.3	45.13	42±2.463
SO_4^{2-}(mg/L)	10.8	4.1	6.5	8.4	7.6	4.5±2.463
HCO_3^-	493	507	580	470	410	410±61.600
Na(mg/L)	27.59	43.68	40.2	38.6	32.5	27.59±6.423
K (mg/L)	7.04	7.82	7.2	7.8	7.1	7.04±0.386
Ca (mg/L)	62.79	57.60	50.62	56.38	48.36	48.36±5.756
Mg (mg/L)	8.77	9.72	10.20	10.43	9.63	9.3±0.640
Fe(mg/L)	0.083	0.038	0.032	0.054	0.113	0.032±0.034
As(mg/L)	0	0	0	0	0	0
FC	0	0	0	0	0	0

Unit: All unit area in mg/L except Temperature in, EC in µS/cm and pH

Table 21

Physico-chemical characteristics of groundwater of Nachole Upazila in October, 2014

Parameters	Sample No. 1 Gonoir (Plot-120)	Sample No. 2 Pos. Mirzapur (Plot-125)	Sample No. 3 Sreerampur (Plot-70)	Sample No. 4 Khandura (Plot-134)	Sample No. 5 Sobdolpur (Plot-318)	Mean±SD
Temperature	25.9	26.4	26.3	26.1	26.2	25.9±0.192
pH	7.5	7.2	7.2	7.1	7.4	7.1±0.164
EC (µS/cm)	812	884	880	805	790	790±44.376
TDS(mg/L)	380	400	300	380	300	300±48.166
TH	122	148	159	146	150	122±13.784
Cl^- (mg/L)	10.05	13.40	10.05	13.35	16.75	10.05±2.800
SO_4^{2-}(mg/L)	16.8	10.7	9.7	8.6	11.5	8.6±3.177
HCO_3^-	301	415	380	410	470	299±61.868
Na(mg/L)	27.59	22.99	45.98	32.5	37.2	22.99±8.881
K (mg/L)	3.90	3.13	4.69	6.5	4.9	3.13±1.1261
Ca (mg/L)	35.24	51.9	53.18	49.7	43.57	34.2±7.402
Mg (mg/L)	8.3	4.51	6.40	9.02	9.97	4.51±2.185
Fe(mg/L)	0.07	0.033	0.085	0.104	0.103	0.033±0.056
As(mg/L)	0	0.003	0	0	0	0±0.001
FC	0	0	0	0	0	0

Unit: All unit area in mg/L except Temperature in, EC in µS/cm and pH

Table 22

Physico-chemical characteristics of groundwater of Gomastapur Upazila in October, 2014

Parameters	Sample No. 1 Akkelpur (Plot-709)	Sample No. 2 Chalkvobani (Plot-218)	Sample No. 3 Gorbari (Plot-341)	Sample No. 4 Khoirabad (Plot-1163)	Sample No. 5 Bosonitola (Plot-436)	Mean±SD
Temperature	26.2	26.0	26.1	26.1	26.3	26±0.114
pH	7.1	7.1	7.3	7.2	7.3	7.1±0.100
EC (µS/cm)	902	923	1050	880	870	870±72.815
TDS(mg/L)	550	390	550	480	410	390±75.366
TH	96	105	115	112	124	96±10.55
Cl^- (mg/L)	33.5	60.9	77.05	67.0	20.1	20.1±23.933
SO_4^{2-}(mg/L)	16.2	18.5	12.04	15.6	17.8	12.04±2.518
HCO_3^-	418	312	490	420	390	312±64.203
Na(mg/L)	41.38	20.69	25.7	35.4	37.0	20.69±8.546
K (mg/L)	6.26	7.43	6.5	6.1	7.2	6.1±0.587
Ca (mg/L)	37.16	39.09	36.52	43.57	45.49	36.52±3.976
Mg (mg/L)	5.71	4.898	5.69	5.71	5.609	4.898±0.352
Fe(mg/L)	0.050	0.989	0.249	0.937	0.908	0.07±0.442
As(mg/L)	0	0.003	0	0	0	0±0.001
FC	0	0	0	0	0	0

Unit: All unit area in mg/L except Temperature in, EC in µS/cm and pH

Table 23

Physico-chemical characteristics of groundwater of Bholahat Upazila in October, 2014

Parameters	Sample No. 1 Borojambaria (Plot-904)	Sample No. 2 Helachi (Plot-334)	Sample No. 3 Modhupur (Plot-2123)	Sample No. 4 Modhupur (Plot-655)	Sample No. 5 Khalealompur (Plot-508)	Mean±SD
Temperature	25.9	25.8	26.4	26.2	26.2	25.8±0.245
pH	7.3	7.2	7.3	7.1	7.0	7±0.130
EC (µS/cm)	1084	998	1010	980	1020	980±39.583
TDS(mg/L)	540	490	550	510	520	490±23.875
TH	129	105	95	155	90	90±27.022
Cl^- (mg/L)	73.4	33.5	33.5	20.1	13.4	13.4±23.278
SO_4^{2-}(mg/L)	5.0	13.1	11.0	7.9	8.1	5±3.116
HCO_3^-	475	413	450	430	440	411±23.137
Na(mg/L)	29.89	29.89	28.5	27.6	28.9	27.6±0.974
K (mg/L)	4.69	3.90	4.5	4.1	4.2	3.9±0.316
Ca (mg/L)	62.29	46.14	51.45	69.73	39.09	39.09±12.313
Mg (mg/L)	10.68	3.56	5.49	6.64	4.75	3.56±2,731
Fe(mg/L)	0.002	0.025	0.045	0.089	0.032	0.025±0.178
As(mg/L)	0	0.0	0	0	0	0
FC	0	0	0	0	0	0

Unit: All unit area in mg/L except Temperature in, EC in µS/cm and pH

ii. pH

The highest pH of DTWs measured was 8.2 and 7.9 obtained in March (pre-monsoon) and October (post-monsoon), respectively and the lowest was 7.3 and 7.0 pre and post-monsoon, respectively (Table 14-23). The result indicates the groundwater pH was nearly and slightly varies with time. Sundar and Saseetharan (2008) supported the present finding where the groundwater pH in pre-monsoon in Tamil Nadu in India was higher than the post-monsoon. Higher pH in water during pre-monsoon was more than other seasons due to decrease the volume of water. The Water pH of DTWs in the study area followed in the order: pre-monsoon>post-monsoon.

iii. Electrical conductivity (EC)

The highest mean values of EC were 823 and 980µS/cm for the pre and post-monsoon of DTWs water samples during the study period, respectively (Table 14-23) could be the effect of leaching and subsequent infiltration as the groundwater table was nearer to the surface, which apparently suggests the enhancement of solute in the aquifer. The lowest mean values of EC were measured to be 458 and 703 µS/cm in pre and post-monsoon, 2014, respectively for the DTWs water samples, respectively (Table 14-23). Deshmukh, (2011) supported the present finding where the groundwater EC measured in post-monsoon in Sangamner in India was higher than the pre-monsoon. EC of the DTWs water shambles in the study area followed: post-monsoon>pre-monsoon.

v. Total Dissolved Solids (TDS)

The highest mean value of TDS of tubewells was found to be 474 and 490 mg/L in pre and post-monsoon, 2014, respectively and the lowest was 293 and 300 mg/L in pre and post-monsoon during the study period (Table 14-23). During post-monsoon season, groundwater is percolation through soil that increased TDS in the post-monsoon season. TDS of groundwater in the study area followed: post-monsoon>pre-monsoon.

vi. Total hardness (TH)

The highest mean value of TH for DTWs was measured to be 350 and 459 mg/L in pre and post-monsoon, 2014, respectively and the lowest was 85 and 90 mg/L in pre and post-monsoon during the study period (Table 14-23). A similar observation was made by Shende *et al.*, (2013). The analysis result of the TH illustrate that water samples for the pre-monsoon and post-monsoon were hard to very hard types. TH of water of DTWs in the order: post-monsoon>pre-monsoon.

4.7.2 Variation of anionic parameters in groundwater

i. Chloride ion (Cl^-)

The highest mean value of Cl^- concentration of DTWs water samples was found to be 40.5 and 40.2 mg/L in pre and post-monsoon in 2014, respectively and the lowest was 9.5 and 10.05 mg/L in pre and post-monsoon, respectively during the study period (Table 14-23). The significant increased of Cl- in the post-monsoon rather than pre-monsoon for the DTWs water due to substantiate the high leaching of salt with percolating rain water and anthropogenic sources of chloride include fertilizers, and human and animal waste. Deshmukh (2011) supported the present finding where the Cl^- in groundwater samples in Sangamner in India was higher in the post-monsoon than the pre-monsoon. Cl^- concentration of water of the DTWs water in the study area followed in the order: post-monsoon>pre-monsoon.

ii. Sulphate ion (SO_4^{2+})

The highest mean (SO_4^{2+}) concentration of DTWs was measured to be 11 and 12.04 mg/L in pre and post-monsoon in 2014, respectively and the lowest was 4.1 and 4.5 mg/L in pre and post-monsoon, respectively during the same period (Table 14-23). Deshmukh (2011) supported the present finding where the (SO_4^{2+}) in groundwater samples in Sangamner in India was higher in the post-monsoon than the pre-monsoon. The change in (SO_4^{2+}) concentration in water samples was negligible with respect to seasons although slightly increase was noticed in the post-monsoon season and it may be due to the action of leaching and anthropogenic activities. The (SO_4^{2+}) concentrations of water of DTWs water samples in the study area followed in the order: post-monsoon > pre-monsoon.

iii. Bicarbonate ion (HCO_3^-)

The highest mean value of HCO_3^- of DTWs water was 413 and 411 mg/L in pre and post-monsoon, 2014 and the lowest was 301 and 299 mg/L in pre and post-monsoon, respectively during the same period (Table 14-23). Mishra *et al.*, (2011) supported the present finding where the HCO_3^- in groundwater samples in Maddhya Pradesh, India was higher in the pre-monsoon than the post-monsoon. Lowering of HCO_3^-values could be the dilution effect of rainwater infiltration during the monsoon season leading to higher groundwater level. Due to the origin of HCO_3^- related to the aquifer lithology and the concentration effect which increase its concentration in pre-monsoon season. HCO_3^- in water of the DTWs in the study area was followed: pre-monsoon>post-monsoon.

4.7.3 Variation of major catatonic parameters in groundwater

i. Sodium ion (Na^+)

The highest mean value of Na^+ concentration of DTWs was measured to be 27.55 and 27.6 mg/L in pre and post-monsoon in 2014, respectively and the lowest was 20.5 and 20.69 mg/L in pre and post-monsoon, during the same period (Table14-23). The results show that the concentration of Na^+ was nearly same in pre- and post-monsoon. Venugopal *et al*., (2009) and Singh *et al*., (2011) illustrated a similar observation of Na^+ concentration in groundwater samples in Chennai and Noida Metropolitan City in Uttar Pradesh in India.

ii. Potassium ion (K^+)

The highest mean value of K^+ concentration of DTWs was found to be 7.0 and 7.04 mg/L in pre and post-monsoon, 2014 and the lowest was 3.02 and 3.13 mg/L in pre and post-monsoon, during the same period (Table 14-23). The result show that the concentration of K^+ were nearly the same in pre and post-monsoon Kuldip-Sing *et al*., (2011), reported that the K^+concentrations in groundwater samples in Bathinda district of Punjab, northwest India was found higher in the post-monsoon than the pre-monsoon and the results supported the present study findings.

iii. Calcium ion (Ca^{2+})

The highest mean value of Ca^{2+} concentration of DTWs was determined to be 51.3 and 50.62 mg/L in pre and post-monsoon in 2014, respectively and the lowest was 35.24 and 34.2 mg/L in monsoon, 2010 during the study period (Table 14-23). A report showed by Kuldip-Sing *et al*., (2011) on Ca^{2+} concentration in DTWs water in Bathinda district of Punjab in India that the ionic concentration in pre-monsoon water samples was higher than the post-monsoon season.

iv. Magnesium ion (Mg^{2+})

The highest mean value of Mg^{2+} concentration of DTWs was measured 8.77 and 9.3 mg/L in pre and post-monsoon in 2014, respectively and the lowest was 3.56 and 4.2 mg/L in pre and post-monsoon during the same period (Table 14-23). There was a little increase in the concentration of Mg^{2+} during the post-monsoon than pre-monsoon.

Several reports showed the similar observation for Mg^{2+} concentration in groundwater samples (Kuldip-Sing *et al.*, 2011; Ravichandan and Jayaprakash, 2011 and Shende *et. al*., 2013).

v. Iron (Fe)

The highest mean value of Fe ion concentration of DTWs was found to be 0.05 and 0.07 mg/L in post-monsoon, 2009 and the lowest was 0.02 and 0.025 mg/L in pre and post-monsoon, during the same period (Table 14-23). The iron presence in post-monsoon water samples were found slightly higher than the pre-monsoon, however the results was very encouraging as the concentration was very low. Raju (2006a) supported the present finding where the Fe ion concentration in groundwater samples in Tirumala-Tirupati environs in India was higher in the post-monsoon than pre-monsoon.

vi. Arsenic

Arsenic concentration was not detected in most of the collected DTWs water samples. Only 2-3 samples showed the presence of arsenic, but fortunately the concentrations were far below the permissible limit indicating suitability of groundwater of the study area for agricultural or domestic purpose uses.

The analysis results of the hydro-chemical composition of the DTWs water in Chapai Nawabganj district City showed that the groundwater of the study area was neutral to slightly alkaline pH, hard to very hard and fresh category. Ca^{2+} was the dominant ionic species among the cations of the DTWs water samples, with an average of 50.37 mg/L (range 35.24-69.9 mg/L) whilst the other determined cations were Na (20.5 -45.98 mg/L), Mg (3.56 - 13.76 mg/L), K (3.02-7.82 mg/L), Fe (0.002- 0.88 mg/L), and As (0.00-0.003 mg/L). The catonic order of the groundwater were: Ca^{2+}> Na^{+}> Mg^{2+}> K^{+}> Fe^{3+}> As(total). Among the anions, HCO_3^- was the dominant species with an average of 413.78 mg/L (range 301-580 mg/L) whilst the concentrations of Cl^-, and SO_4^{2-} ranged from 9.5 to 77.05, 4.1 to 16.8 and 0.10 to 7.27 mg/L, respectively in the water samples. The major anions of the DTWs water were followed the order of HCO_3^-> Cl^-> SO_4^{2-}. So, Ca^{2+} and HCO_3^- were the dominant cation and anion, respectively among the ionic parameters in the groundwater samples.

4.8 Hydro-geochemical facies and water types

In order to understand the hydro-chemical facies and water types of groundwater in the study area, the concentrations of major cations and anions were plotted in the Piper tri-linear diagram using AQUACHEM software (Figure 32). In the Piper diagram, overall average major cations and anions are plotted in the two base triangles, and the overall information from the two triangles was combined together on a quadrilateral (Piper, 1944). The ternary anion diagram relating HCO_3^-, SO_4^{2-} and Cl^- shows that most of the groundwater samples contain a high amount of HCO_3^- and plotted points cluster toward the alkalinity apex with secondary trends toward Cl^- and SO_4^{2-}. The cation diagram (Figure 31) show that the majority of groundwater samples contained Ca^{2+}+Mg^{2+} higher than Na^++K^+. The diagram shows that HCO_3^- and Ca^{2+} were the dominant ions in groundwater samples. Therefore, most of the analyzed DTWs water samples fall in the field of Ca^{2+} - HCO_3^- type in the quadrilateral diagram during the pre, post-monsoon and monsoon (Figure 32). Sadashivaiah *et al.*, (2008) illustrated the same water type of DTWs water in Tumkur Taluk, Karnataka State in India.

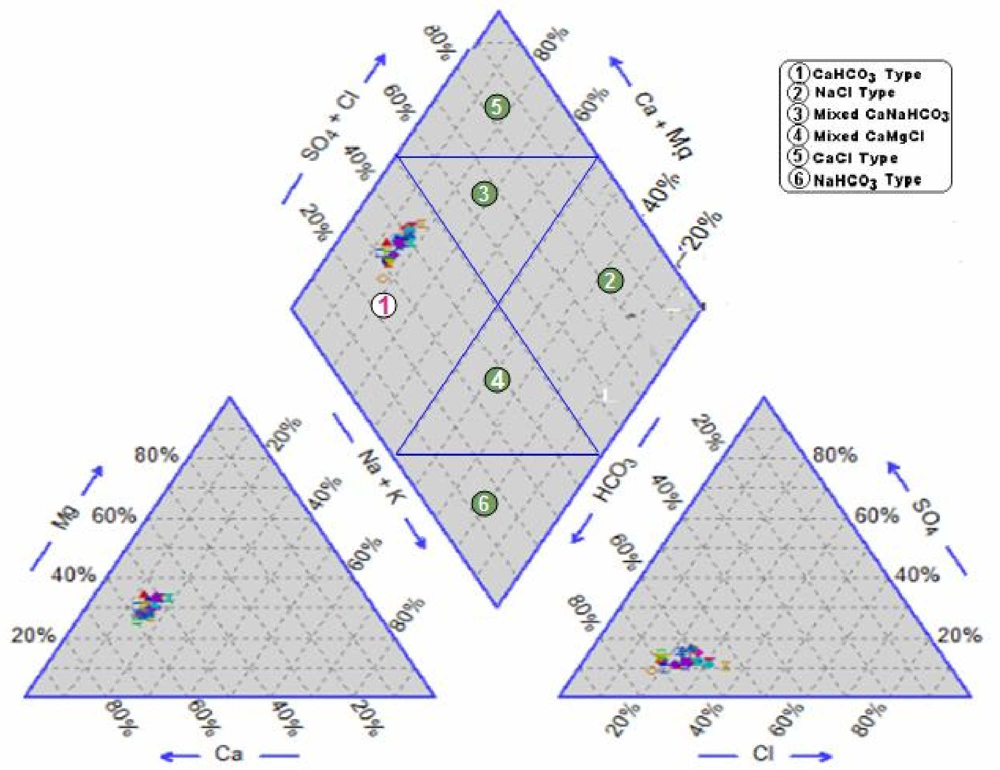

Figure 32 Hydro-chemical facies of groundwater in Chapai Nawabganj in Piper diagram constructed using AQUCHEM software (water type: Ca^{2+} - HCO_3^-).

As the Mg^{2+} concentration in water samples was lower compared to the Ca^{2+} concentration, thus the results suggests that the water type of this area was considered to be Ca^{2+}- HCO_3^-. The obtained water type may be the cause of weathering of silicate and dissolution of carbonate minerals in the aquifer zone of the study area.

4.9 Geo-chemistry of groundwater

4.9.1 Geochemical processes of groundwater

The rock-water interaction generally includes chemical weathering of rock forming minerals, dissolution-precipitation of carbonates, and ion exchange between water and clay minerals. The abundance and distribution of elemental ions such as Ca^{2+}, Mg^{2+}, Na^+, K^+, HCO_3^-, SO_4^{2-} and Cl^- in the water are dependent on erosion and chemical weathering of the rocks in the source area. Interaction between groundwater and its surrounding minerals in the alluvium may be the main process for the observed chemical characteristics of groundwater in the study area.

4.9.2 Fecal Coliform (FC)

Fecal coliform (FC) was not found in any collected DTWs water samples in the study area indicating its suitability for all purpose uses.

The analysis results suggest that the concentration of TH, HCO_3, Ca, Na, K, Mg, and Fe, ions in water were the cause of weathering of aquifer materials. So, groundwater of Chapai Nawabganj district shows a wide range of characteristics in terms of physical, chemical and microbial parameters during two seasons. The study observes that the quality of groundwater was very much suitable for irrigation and domestic purposes.

4.10 Impact of Groundwater over Withdrawal on Environment

Groundwater is the major source of freshwater supply in many areas of south-east Asia. The water is being pumped from beneath the ground faster than it is being replenished through rainfall in many places. The result is depleting water tables, empty wells, higher pumping costs, quality deterioration and, in coastal areas, the intrusion of saltwater from the sea which degrades the groundwater.

Irrigation is the main cause of groundwater overexploitation in Barind area threatens sustainable resource management. The study results identified the groundwater extraction of Chapai Nawabganj district for irrigation as a critical environmental concerned. The study observed the below average rainfall has another causes of groundwater depletion due to lower recharge and thus further aggravated the situation in the study area. The key impediments to potentiality of groundwater have been identified as over exploitation of groundwater use in *Boro* rice cultivation in the area.

The results illustrate the overexploitation of groundwater in Nachole Upazila has led to 10 m depletion in 10 years during study period. The scenario of water level depletion of the Upazila for cast the drought and water scarcity in the area will prevail if the unplanned groundwater extraction is continued in the long run. Despite a slow depletion of groundwater level in other Upazilas during the study period, a holistic approach in water resource management is very much needed for sustainable environment. A report showed that overexploitation of the Po River in the region of the Milan aquifer has led to a 25 m (even up to 40 m) decrease in groundwater levels over the last 80 years (Benoît and Comeau, 2005). In Spain, more than half of the abstracted groundwater volume is obtained from areas facing overexploitation problems (Francesc and Pilar 2001. The simple indication that groundwater withdrawals are exceeding recharge, thus the water table is declining, and the situation is common throughout the world. A number of examples could be stated in this regard, but needed to insure irrigation water for *Boro* rice cultivation in the region. Overdraft of groundwater for irrigation purpose has adverse effects on water table and has dropped rapidly about 30 m with 10 to 15 years in many areas in south East Asia. Nebel and Wright reported that irrigation farming has already come to a halt in many parts in the USA, and it is predicted that over the next 10 years another 3.5 million acres (1.4 million ha) in this region will be abandoned or converted to dry land farming (ranching and production of forage crops) because of water depletion. Although running out of water is the obvious eventual conclusion of overdrawing groundwater, falling water table have other consequences before the water is entirely depleted.

Surface waters are also affected by falling water tables. The water table is essentially at or slightly above the ground surface in many river basins. Further, as water tables drop springs and seeps dry up, diminishing streams and rivers even to the point of dryness. Thus, excessive groundwater removal leads to the same effects as diversion of surface water.

Report shows a lot of examples of land subsidence occurred in various parts in the world due to groundwater level depletion. Land subsidence is also a serious problem in New Orleans, sections of Arizona, Mexico City, and many other places throughout the world (Ram, 2001). But such an incidence has yet been found in the district and has less chance to be happened in near future. However precautions would be made ahead of any incidence to be taken place.

Another problem resulting from dropping water tables is saltwater intrusion**.** But a few possibility of salt water intrusion in this area would consider at moment due to geographical location of the study area.

Groundwater for irrigation use in Barind tract is increasing day by day. The quality of groundwater primarily depends on ground-water resources that are used for public and domestic supply. Groundwater over exploitation has increased the chance to deteriorate the water quality. The introduction of contaminants into groundwater aquifer through human or natural activities deteriorated the water quality. The most significant diffuse contaminant of groundwater in Barind tract is arsenic due groundwater pumping which releases As (V) and As(III) on pyrite in continuously anoxic environments or on pyrite in intermittently oxic/anoxic environments (Sun *et al*., 2012). Liu *et al*. (2003) reported the water pumped from deeper aquifer has introduced excess dissolved oxygen that in turn oxidizes the original immobile minerals, releasing arsenic and other ions. Glennon (2004) illustrated that higher temperatures in lower ground levels facilitate in dissolving elements including arsenic, fluoride and heavy metal ions that are more prevalent at deeper levels. The consumption of such contaminated water leads to the well known "Arsenicosis" disease and the disease has been reported in Southern parts of India and Bangladesh (Stollenwerka, 2007; Kamra *et al*., 2002). Despite the above discussion on water quality deterioration due to overdraft groundwater, arsenic was not detected in any DTW water samples collected in the study. However, elevated amount of arsenic was found in DTWs in the region (Smedley, 2002) suggesting sustainable water extract.

The groundwater management for sustainable irrigation and crop production in the region is imperative. A well planned water resource management would have to be taken to achieve sustainable use of groundwater for irrigation aiming to achieve food security as well as ecological friendly environment. It is also imperative to follow the best irrigation management practices and climate change adaptation techniques for sustainable use of groundwater and environmentally-friendly. The sustainability of groundwater ultimately depends on balancing withdrawals with rates of recharge.

Planning, development and management of groundwater and water resources as a whole would be done in line with the formulated policies and strategies. The study has identified a number of key areas for attaining sustainability of groundwater use, which would assist in achieving the sustainable food security of the country as well as protection of ecosystem. River channel irrigation system has already implemented in some areas in Nawabganj and Nachole Upazilas irrigation but the project area is not enough to fulfill aspiration of local people.

Although irrigation for *Boro* cultivation has explored opportunity to farmers to grow modern rice varieties on the same parcel of land and at the same time has led to environmental degradation including decline of groundwater level, soil quality and surface water quality due to run-off harmful agrochemicals (Hossain 2009; Dey and Haq 2008).

Conclusions

CONCLUSIONS

This research program has considered rainfall, water level fluctuation and drilling log data, and water quality parameters of five Upazilas in Chapai Nawabganj district under the Barind area in view of maintaining sustainable irrigation water supply to achieve food security as well as water resource management. The study area consisted of five Upazilas in the Barind area, namely Nawabganj, Shibganj, Nachole, Gomastapur and Bholahat. The study largely considered secondary data collected from different organizations and five boring log samples were collected from five Upazilas of Chapai Nawabganj district. A total of 50 representatives deep tubewells (DTWs) water samples were collected from 5 selected locations of each Upazila during the month of March (pre-monsoon) and October (post-monsoon), 2014.

The experimental data were statistically analyzed using various software and the results were discussed to interpret the geochemical characteristics, water type, and water quality. The study was attempted to understand the fluctuation of groundwater table, potentiality, water quality, and as well as to assess storage capacity.

The study results show that the maximum water tables depletion were found between February to May and elevated water tables were found throughout September and October as expected due to post-monsoon groundwater level. The study results also illustrate the maximum water level recorded was about 30 m below the surface at Nachole Upazila in 2010 and minimum water level recorded was about 1.0 m below the surface at Shibganj Upazila in 2004.

In Nawabganj Upazila, the maximum depletion of water level was found to be 17.51 m in 2010 and minimum was 8.60 m in 2004. In Shibganj Upazila, the maximum depletion of groundwater level was found to be 8.47 m in 2011 and the minimum was about 1.0m 2004. In Nachole Upazila, the maximum water level was observed to be 29.5 m in 2010 and the minimum was 10.0 m in 2002. In Gomastapur Upazila, the maximum water level was 16.5 m in 2009 and minimum was 7.0m in 2002. In Bholahat Upazila, the maximum water level was observed to be 16.0 m in 2011 and minimum was 3.5 m in 2002. The results illustrate that the highest groundwater depletion was about 29 m found at Nawabganj Upazila in 2010 and the lowest was about 5m at Shibganj in 2003.

A 10-year rainfall data of the district shows that the maximum annual rainfall recorded was 1804 mm in 2007. Since then, rainfall was gradually decreasing for consecutive three years, but it was increased 439 mm in 2011 from 1015 mm recorded in the previous year. The results show that Nachole Upazila received the highest rainfall (2029mm) in 2007 and Bholahat Upazila received the lowest rainfall (897mm) in 2010 during the study period of the area. The average rainfall received in Chapai Nawabganj district was 1372 mm during 2002-2011.

The runoff was estimated from the rainfall and the results show the maximum estimated runoff was 304 mm found in 2007 at Nachole Upazila and the minimum was 121 mm in 2003 at Shibganj Upazila during the study period. Without any exception, runoff was gradually decreasing in the study area for consecutive three years since 2007, but it was increased in all Upazilas of the district in 2011 as expected due to higher rainfall received.

The estimated infiltration results of Chapai Nawabganj district in Barind area illustrate that the highest infiltration was 1700 mm found in 2007 at Nachole Upazila and the minimum was 657 mm in 2003 at Shibganj Upazila. In the study area, a decreasing trend in infiltration was observed for consecutive three years in the study since 2007, but increased amount was found in 2011 in all Upazilas due to higher rainfall received this year. The amount of runoff and infiltration were varied with rainfall received as expected. The highest annual rainfall received was 1793 mm in 2007 and the lowest was 1025 mm in 2010 in the district. The results show a good relation among the parameters indicating that the higher amount was the rainfall, the higher amounts were the estimated runoff and infiltration.

A good trend of water table fluctuations of Chapai Nawabganj district was found during 2002 to 2011. The results illustrate that the overall water table showed the minimum water level was found in 2004 and maximum in 2011. The graphs show wave like fluctuation curves, where the highest depletion occurred during March-April and then the water table moved upward direction slowly and reached at minimum level during

September-October and again slowly depleted until rain started in May. The study results reveal that a good relation between rainfall and water table fluctuations was observed where the groundwater table was recharged through the rainfall. The overall yearly water table declining trend indicate that unsustainable withdrawal of groundwater for irrigation and domestic purposes would be played a vital role in water table depletion in the study area. Fluctuation of groundwater level was different in magnitude depending on the extraction and recharge in different locations.

Specific yield of the five Upazilas were determined and the values were found around 10 (%) which indicate good permeability of the areas, except Bholahat Upzila, where the value was 8.4 (%) indicating low permeability. The storage capacity of the five Upazilas in Chapai Nawabganj district was estimated using the area, the average fluctuation and specific yield storage of groundwater and the results illustrate that Nachole Upazila has comparatively a large storage volume, i.e., 49,305 ha-m, but the other Upazilas have a storage capacity between 8000 to 18000 ha-m. The storage capacity of the five Upazilas was followed the order: Nachole>Nawabganj>Shibganj>Gomastapur>Bholahat.

A total of 43 DTWs at the rate of 2 cusec capacity were operated for 800 hours/year at Nawabganj Upazila and the extraction of groundwater/year of the Upazila was 3471 ha-m. The highest number of DTWs was installed at Nachole Uapzila in the district and the extracted amount was 8848 ha-m indicating excessive extraction concerned sustainable water management.

A total of 50 DTWs water samples were collected twice, i.e., March and October in 2014 from five locations of each Upazila of Chapai Nawabganj district in the Barind area and analyzed for physico-chemical parameters. The highest temperature of DTWs was found to be 28.45 and 26.5°C in March (pre-monsoon), and October (post-monsoon), respectively in the study area. The lowest was 27.8°C and 25.8°C in March (pre-monsoon), and October (post-monsoon) 2014, respectively.

The analysis results of the hydro-chemical composition of the DTWs water in Chapai Nawabganj district showed that the groundwater of the study area was neutral to slightly alkaline pH, and fresh category. Ca^{2+} was the dominant ionic species among the cations of the DTWs water samples, with an average of 50.37 mg/L (range 35.24-69.9 mg/L) whilst the other determined cations were Na (20.5 -45.98 mg/L), Mg (11.52-35.75 mg/L), K (0.22-11.78 mg/L, Fe (0.14- 8.04 mg/L), and As (0.001-0.081 mg/L. The catonic order of the groundwater was: Ca^{2+}> Mg^{2+}> Na^{+}> K^{+}> Fe^{3+}> As(total). Among the anions, HCO_3^- was the dominant species with an average of 245.301 mg/L (range 60-510 mg/L) whilst the concentrations of Cl^-, and SO_4^{2-} ranged from 17.43 to 110.99, 16.54 to 71.81 and 0.10 to 7.27 mg/L, respectively in the water samples. The major anions of the DTWs water were followed the order of HCO_3^-> Cl^-> SO_4^{2-}. So, Ca^{2+} and HCO_3^- were the dominant cation and anion, respectively among the ionic parameters in the groundwater samples.

In order to understand the hydro-chemical facies and water types of groundwater in the study area, the concentrations of major cations and anions were plotted in the Piper tri-linear diagram using AQUACHEM software. The ternary anion diagram relating to HCO_3^-, SO_4^{2-} and Cl^- shows that most of the groundwater samples contain a high amount of HCO_3^- and plotted points cluster toward the alkalinity apex with secondary trends toward Cl^- and SO_4^{2-}. The cation diagram show that the majority of groundwater samples contained Ca^{2+}+ Mg^{2+} higher than Na^{+}+K^{+}. The diagram shows that HCO_3^- and Ca^{2+} were the dominant ions in groundwater samples. Therefore, most of the analyzed DTWs water samples fall in the field of Ca^{2+}-HCO_3^- type in the quadrilateral diagram during the pre and post-monsoon. As the Mg^{2+} concentration in water samples was lower compared to the Ca^{2+} concentration, thus the results suggest that the water type of this area was considered to be Ca^{2+}- HCO_3^-. The obtained water type may be the cause of weathering of silicate and dissolution of carbonate minerals in the aquifer zone of the study area.

The analysis results suggest that the concentration of TH, HCO_3, Ca, Na, K, Mg, and Fe, ions in water were the cause of weathering of aquifer materials. So, groundwater of Chapai Nawabganj district in the Barind area shows a wide range of characteristics in terms of physical, chemical and microbial parameters during two seasons. Fecal coliform (FC) was not found in any collected DTWs water samples in the study area. The study observes that the quality of groundwater was very much suitable for irrigation and domestic purposes.

The results illustrate the overexploitation of groundwater in Nachole Upazila has led to 10 m depletion in 10 years during study period. The scenario of water level depletion of the Upazila forcast the drought and water scarcity in the area will prevail if the unplanned groundwater extraction is continued in the long run. Despite a slow depletion of groundwater level in other Upazilas during the study period, a holistic approach in water resource management is very much needed for sustainable environment. Irrigation is the main cause of groundwater overexploitation in Barind area threatens sustainable resource management. The study results identify the groundwater extraction of Chapai Nawabganj district for irrigation as a critical environmental concerned. The study observed the below average rainfall has another cause of groundwater depletion and thus further aggravated the situation in the study area. The key impediments to potentiality of groundwater have been identified as over exploitation of groundwater use in *Boro* rice cultivation in the Barind area.

There was no report of land subsidence in the study area till October 2014 but precautions would be made ahead of any incidence to be taken place. Groundwater over exploitation has increased the chance to deteriorate the water quality. The introduction of contaminants into groundwater aquifer through human or natural activities deteriorated the water quality. Despite the overdraft of groundwater, arsenic was not detected in any DTW water samples collected in the study.

The groundwater management for sustainable irrigation and crop production in the region is imperative. A well planned water resource management would have to be taken to achieve sustainable use of groundwater for irrigation aiming to achieve food security as well as ecological friendly environment. It is also imperative to follow the best irrigation management practices and climate change adaptation techniques for sustainable use of groundwater and environmentally-friendly. The sustainability of groundwater ultimately depends on balancing withdrawals with rates of recharge.

Some of the urgent steps are to be needed in order to maintain sustainable water resource management and development of irrigated agriculture projects in the Barind area and these are as follows:

- Campaign to promote water harvesting including rainwater
- Establish projects to promote the dependency on surface water for irrigation water supply
- Prevent unsustainable exploitation of the aquifers.
- Store water in large reservoirs or cannels during monsoon and use substantial amount in dry season.
- Ensure efficiency, economy and equity in water use through cooperative management of water resource in command areas.

Thus, peoples' participation in water conservation, efficient use and demand management will foster both sustainable food and irrigation water security in the area.

To ensure this, the planner should have information on the current state of resources and their future uses and the possible use of alternatives. Mitigation measures would be made if the water uses exceed, or threaten to exceed, the existing capacity of the aquifer.

Recommendation for Future Scope of Research and Study

There is considerable scope for improving groundwater potentiality through assessing the water table fluctuation and analyzing the water quality parameters. Therefore, further research works and study would be conducted considering a 30-year groundwater fluctuation data on the entire Barind area and the analysis of water quality parameters for pre-monsoon, monsoon and post-monsoon covering two years for better understanding of the groundwater potentiality and sustainable water management of the area.

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Appendix

Appendix-1
Groundwater level at five Upazilas of Chapai Nawabganj district

Table 1.1 Groundwater level at Khamar union of Nawabganj Upazila

YEAR	JANUARY		FEBRUARY		MARCH	
	1st test	2nd test	1st test	2nd test	1st test	2nd test
2002	37' 0"	37' 8"	40' 3"	42' 9"	45' 6"	48' 3"
2003	38' 10"	39' 2"	38' 9"	38' 1"	43' 3"	48' 0"
2004	37' 1"	39' 0"	43' 2"	46' 4"	48' 9"	51' 2"
2005	36' 5"	38' 3"	39' 5"	40' 2"	40' 8"	41' 0"
2006	36'10"	37'5"	37'9"	38'1"	38'4"	38'9"
2007	37'10"	38'4"	38'10"	39'2"	40'4"	41'6"
2008	50'10"	51'6"	51'9"	52'0"	52'8"	53'0"
2009	46'10'	49'6"	50'9"	51'0"	53'2"	53'0"
2010	55'5"	56'9'	56'8"	57'6"	57'7"	57'11"
2011	54'2"	55'1"	56'2"	56'8"	56'10"	57'11"

YEAR	APRIL		MAY		JUNE	
	1st test	2nd test	1st test	2nd test	1st test	2nd test
2002	49' 4"	50' 9"	43' 9"	38' 0"	36' 5"	33' 2"
2003	46' 5"	44' 0"	45' 7"	47' 4"	45' 10"	44' 0"
2004	45' 4"	40' 6"	40' 0"	39' 8"	38' 0"	37' 7"
2005	41' 11"	42' 7"	41' 1"	40' 7"	40' 2"	39'5"
2006	39'4"	40'0"	39'0"	38'7"	38'2"	38'0"
2007	42'2"	42'10"	42'0"	41'6"	39'0"	38'6"
2008	53'2"	53'8"	53'11"	53'6"	50'4"	50'0"
2009	54'0"	54'2"	58'9"	54'8"	54'10"	55'1"
2010	58'0"	58'1"	57'10"	57'7"	57'6"	57'5"
2011	58'3"	56'11"	54'3"	47'7"	46'8"	45'6"

YEAR	JULY		AUGUST		SEPTEMBER	
	1st test	2nd test	1st test	2nd test	1st test	2nd test
2002	36' 8"	40' 10"	37' 4"	35' 5"	33' 3"	30' 4"
2003	41' 9"	38' 0"	37' 7"	33' 2"	32' 1"	31' 5"
2004	35' 4"	33' 6"	33' 1"	32' 7"	30' 0"	28' 2"
2005	39'2"	38'10"	38'6"	38'3"	38'0"	37'10"
2006	37'6"	37'0"	36'10"	36'7"	35'0"	32'2"
2007	36'10"	34'6"	32'4"	31'6"	32'2"	33'0"
2008	48'2"	47'0"	42'6"	40'4"	37'9"	36'2"
2009	55'3"	55'10"	53'7"	53'1"	52'8"	53'3"
2010	57'2"	55'1"	54'5"	53'8"	51'10"	51'1"
2011	50'9"	50'3"	45'11"	34'5"	35'6"	32'4"

YEAR	OCTOBER		NOVEMBER		DECEMBER	
	1st test	2nd test	1st test	2nd test	1st test	2nd test
2002	31' 0"	32' 6"	32' 6"	33' 0"	35' 6"	38' 4"
2003	31' 2"	31' 4"	32' 0"	33' 3"	34' 8"	35' 5"
2004	27'11"	28'1"	28'11"	29'7"	30'5"	31'4"
2005	37'7"	37'5"	37'6"	37'8"	37'2"	36'10"
2006	32'4"	33'6"	35'2"	34'10"	36'3"	36'9"
2007	33'8"	34'4"	39'6"	42'10"	46'2"	50'4"
2008	36'10"	37'6"	37'8"	38'0"	40'10"	42'2"
2009	53'6"	54'1"	54'5"	54'8"	54'10"	54'11"
2010	51'0"	51'8"	52'2"	52'6"	52'7"	53'5"
2011	38'3"	41'6"	39'9"	42'7"	42'10"	43'8"

Table 1.2 Groundwater level at Jhilim union of Nawabganj Upazila

YEAR	JANUARY		FEBRUARY		MARCH	
	1st test	2nd test	1st test	2nd test	1st test	2nd test
2002	38' 3"	38' 10"	41' 10"	44' 5"	47' 0"	51' 4"
2003	40' 4"	40' 6"	39' 11"	39' 6"	44' 10"	49' 11"
2004	35' 10"	38' 4"	42' 4"	46' 2"	49' 5"	53' 4"
2005	35' 7"	38' 5"	39' 6"	40' 8"	41' 7"	42' 1"
2006	36'1"	36'8"	37'0"	37'4"	37'8"	37'11"
2007	36'8'	37'4"	38'9"	39'3"	41'8"	42'2"
2008	47'2"	47'11"	48'3"	48'10"	49'2"	49'9"
2009	44'1"	47'5"	47'2"	48'5"	50'4"	50'10"
2010	53'3"	54'0"	54'9"	56'1"	56'3"	56'6"
2011	52'2"	53'0"	54'11"	55'2"	54'11"	55'2"

YEAR	APRIL		MAY		JUNE	
	1st test	2nd test	1st test	2nd test	1st test	2nd test
2002	50' 9"	52' 8"	45' 3"	39' 4"	39' 5"	37' 7"
2003	47' 0"	45' 7"	45' 2"	45' 5"	42' 3"	40' 6"
2004	48' 10"	42' 0"	41' 5"	41' 2"	40' 5"	39' 2"
2005	43' 0"	43' 8"	42' 10"	42' 5"	42' 0"	41' 6"
2006	39'5"	40'2"	39'9"	38'7"	38'0"	37'10"
2007	42'9"	43'7"	42'5"	42'0"	39'6"	38'8"
2008	50'0"	50'4"	50'6"	50'2"	48'6"	48'2"
2009	50'11"	50'1"	53'2"	51'6"	51'9"	52'6"
2010	56'7"	56'0"	56'9"	56'3"	56'3"	56'2"
2011	45'1"	46'0"	40'10"	36'8"	35'11"	34'9"

YEAR	JULY		AUGUST		SEPTEMBER	
	1st test	2nd test	1st test	2nd test	1st test	2nd test
2002	39' 9"	42' 7"	39' 4"	37' 6"	35' 0"	32' 0"
2003	38' 5"	35' 2"	33' 7"	31' 10"	31' 4"	30' 8"
2004	37' 6"	36' 0"	34' 2"	33' 8"	31' 4"	29' 6"
2005	41' 1"	40' 9"	40'6"	40'2"	40'0"	39'10"
2006	37'0"	36'4"	36'0"	35'9"	33'2"	31'0"
2007	36'4"	35'0"	33'2"	32'8"	33'4"	33'10
2008	46'0"	45'2"	42'0"	39'11"	36'8"	34'10"
2009	52'7"	52'10"	51'3"	50'8"	49'6"	50'2"
2010	55'1"	53'3"	52'7"	52'2"	50'6"	50'2"
2011	40'10"	40'6"	35'10"	28'7"	31'5"	29'10"

YEAR	OCTOBER		NOVEMBER		DECEMBER	
	1st test	2nd test	1st test	2nd test	1st test	2nd test
2002	33' 4"	34' 5"	34' 5"	34' 11"	37' 6"	40' 3"
2003	30' 6"	31' 0"	31' 6"	32' 4"	32' 3"	34' 0"
2004	29'4"	29'10"	30'5"	31'3"	31'1"	33'0"
2005	39'8"	39'6"	39'9"	39'11"	39'4"	39'0"
2006	31'8"	32'11"	33'9"	34'4"	34'8"	35'2"
2007	34'5"	35'2"	38'10"	41'7"	44'10"	46'5"
2008	35'4"	36'10"	37'0"	37'3"	39'2"	41'1"
2009	51'1"	52'3"	52'6"	52'10"	52'7"	52'11"
2010	50'3"	50'9'	50'1"	50'8"	50'11"	51'10"
2011	34'3"	37'8"	35'10"	37'10"	38'3"	38'10"

Table 1.3 Groundwater level at Shomaspur union of Nachle Upazila

YEAR	JANUARY		FEBRUARY		MARCH	
	1st test	2nd test	1st test	2nd test	1st test	2nd test
2002	53' 2"	59' 4"	75' 6"	81' 10"	84' 9"	85' 9"
2003	55' 8"	57' 1"	62' 7"	66' 10"	75' 5"	81' 2"
2004	49' 9"	51' 3"	65' 5"	86' 4"	87' 1"	87' 8"
2005	65' 3"	67' 1"	71' 5"	78' 9"	86' 11"	87' 2"
2006	49'8"	50'9"	78'6"	83'5"	89'4"	89'10"
2007	83'3"	85'7"	86'1"	87'3"	86'6"	90'5"
2008	86'4"	88'3"	87'6"	89'2"	89'4"	91'5"
2009	87'2"	87'11"	89'2"	92'8"	92'5"	95'7"
2010	94'5"	96'0"	95'5"	96'9"	97'1"	975"
2011	99'0"	101'0"	101'6"	101'10"	101'11"	102'1"

YEAR	APRIL		MAY		JUNE	
	1st test	2nd test	1st test	2nd test	1st test	2nd test
2002	81' 4"	81' 7"	77' 2"	75' 8"	73' 2"	71' 3"
2003	83' 5"	81' 10"	80' 2"	76' 3"	70' 5"	62' 9"
2004	91' 6"	87' 9"	87' 5"	87' 2"	86' 5"	85' 7"
2005	86'10"	80'1"	79' 7"	77' 10"	77' 6"	77' 3"
2006	90'7"	87'2"	85'5"	83'6"	81'2"	79'0"
2007	86'4"	90'2"	88'2"	89'7"	87'6"	87'2"
2008	92'5"	96'4"	91'7"	90'8"	91'7"	90'8"
2009	96'4"	94'10"	92'5"	91'6"	90'2"	89'1"
2010	98'1"	98'7"	98'1"	97'5"	97'6"	97'1"
2011	101'0"	101'5"	101'4"	100'2"	99'1"	98'2"

YEAR	JULY		AUGUST		SEPTEMBER	
	1st test	2nd test	1st test	2nd test	1st test	2nd test
2002	69' 5"	67' 7"	57' 3"	51' 6"	42' 3"	39' 4"
2003	62' 0"	61' 7"	57' 10"	48' 5"	45' 3"	41' 3"
2004	79' 2"	71' 11"	60' 2"	53' 5"	47' 3"	42' 1"
2005	66' 4"	62' 9"	60'7"	54'3"	70'0"	67'2"
2006	78'3"	76'5"	72'2"	69'0"	81'1"	79'9"
2007	87'6"	86'10"	85'6"	83'9"	82'6"	75'9"
2008	88'4"	87'5"	86'1"	85'2"	84'3"	84'0"
2009	85'6"	85'0"	88'2"	87'7"	87'2"	86'8"
2010	96'10"	96'5"	96'1"	95'10"	94'10"	95'3"
2011	95'11"	94'6"	93'8"	93'5"	101'2"	101'5"

YEAR	OCTOBER		NOVEMBER		DECEMBER	
	1st test	2nd test	1st test	2nd test	1st test	2nd test
2002	37' 0"	38' 10"	44' 4"	45' 9"	49' 2"	53' 4"
2003	39' 6"	37' 8"	41' 5"	43' 11"	46' 5"	48' 2"
2004	44'11"	47'5"	53'10"	58'6"	61' 9"	65' 2"
2005	70'6"	67'8"	67'0"	68'9"	77'6"	79'6"
2006	80'3"	80'10"	82'7"	84'3"	82'3"	83'9"
2007	75'3"	78'2"	80'5"	81'2"	83'1"	84'2"
2008	78'7"	76'5"	85'10"	85'0"	85'9"	86'5"
2009	89'9"	91'10"	89'2"	91'3"	90'2"	90'0"
2010	95'1"	94'10"	94'9"	94'7"	95'3"	95'5"
2011	101'4"	101'2"	100'7"	100'0"	99'2"	98'0"

Table 1.4 Groundwater level at Nejampur union of Nachle Upazila

YEAR	JANUARY		FEBRUARY		MARCH	
	1st test	2nd test	1st test	2nd test	1st test	2nd test
2002	47' 5"	59' 9"	68' 11"	76' 8"	78' 11"	79' 10"
2003	52' 1"	54' 7"	64' 2"	77' 6"	78' 5"	80' 4"
2004	49' 9"	51' 3"	80' 6"	83' 2"	85' 2"	87' 1"
2005	58' 4"	63' 5"	68' 2"	73' 4"	85' 1"	85' 5"
2006	49'8"	50'7"	76'6"	82'5"	88'6"	89'1"
2007	45'7"	47'6"	46'2"	47'5"	84'3"	87'1"
2008	84'6"	93'2"	85'7"	94'4"	87'8"	96'7"
2009	65'6"	66'3"	79'0"	90'0"	86'4"	93'3"
2010	85'3"	85'7"	87'7"	90'11"	91'4"	91'11"
2011	93'4"	93'3"	93'5"	93'7"	93'10"	94'1"

YEAR	APRIL		MAY		JUNE	
	1st test	2nd test	1st test	2nd test	1st test	2nd test
2002	78' 2"	78' 4"	73' 6"	71' 11"	70' 5"	68' 2"
2003	81' 4"	80' 5"	75' 3"	71' 10"	70' 4"	68' 11"
2004	88' 1"	87' 2"	84' 3"	78' 2"	70' 6"	68' 8"
2005	85'10"	86'7"	78' 3"	76' 7"	76' 4"	76' 0"
2006	89'7"	86'6"	86'6"	82'5"	80'8"	79'3"
2007	84'1"	84'2"	84'2"	88'6"	83'8"	83'2"
2008	91'4"	98'11"	90'3"	89'6"	88'2'"	84'10"
2009	92'4"	89'11'	87'8"	85'10"	85'1"	84'7"
2010	91'5"	89'11"	89'0"	88'5"	88'5"	88'0"
2011	93'10"	93'5"	92'0"	91'4"	93'5"	91'4"

YEAR	JULY		AUGUST		SEPTEMBER	
	1st test	2nd test	1st test	2nd test	1st test	2nd test
2002	62' 7"	57' 10"	47' 2"	42' 11"	34' 0"	32' 2"
2003	65' 7"	61' 2"	48' 3"	40' 9"	38' 8"	37' 3"
2004	60' 4"	51' 2"	48' 5"	44' 10"	37' 6"	34' 6"
2005	65' 2"	61' 7"	52'1"	45'7"	50'8"	50'1"
2006	79'4"	76'3"	43'6"	41'4"	39'8"	37'6"
2007	82'9"	81'7"	65'3"	52'8"	48'5"	42'6"
2008	82'4"	81'5"	65'1"	60'2"	59'1"	58'0"
2009	84'6"	83'2"	83'1"	82'7"	82'0"	81'5"
2010	87'10"	87'6"	87'4"	87'1"	92'11"	93'5"
2011	88'8"	85'6"	84'10"	83'8"	90'9"	90'11"

YEAR	OCTOBER		NOVEMBER		DECEMBER	
	1st test	2nd test	1st test	2nd test	1st test	2nd test
2002	31' 2"	33' 3"	26' 0"	27' 4"	46' 0"	49' 0"
2003	37' 6"	36' 2"	32' 2"	33' 4"	34' 8"	36' 4"
2004	31'6"	33'5"	38'6"	43'5"	46' 7"	50' 3"
2005	50'10"	50'4"	50'1"	49'8"	58'6"	60'6"
2006	38'8"	39'4"	39'10"	40'9"	37'10"	38'5"
2007	41'9"	44'3"	60'11"	65'8"	70'5"	72'9"
2008	57'2"	56'1"	64'10"	63'9"	64'3"	64'10"
2009	84'8"	87'8"	87'0"	86'8"	85'2"	84'0"
2010	93'5"	93'4"	90'11"	90'7"	91'0"	91'3"
2011	90'10"	90'8"	90'8"	90'10"	90'7"	90'5"

Table 1.5 Groundwater level at Durlovpur union of Shibganj Upazila

YEAR	JANUARY		FEBRUARY		MARCH	
	1st test	2nd test	1st test	2nd test	1st test	2nd test
2002	11' 3"	11' 7"	12' 6"	12' 10"	13' 6"	14' 4"
2003	11' 3"	11' 8"	12' 4"	12' 6"	12' 8"	12' 10"
2004	13' 9"	14' 5"	16' 3"	18' 9"	19' 0"	19' 1"
2005	10' 7"	11' 3"	19' 3"	21' 7"	21' 9"	21' 0"
2006	12'8"	13'3"	14'11"	17'3"	23'2"	24'9"
2007	12'4"	13'1"	15'2"	18'6"	20'8"	23'3"
2008	12'6"	13'4"	15'5"	18'4"	20'9"	23'5"
2009	14'8"	15'3"	18'1"	20'2"	22'7"	25'9"
2010	18'2"	18'10"	19'2"	19'6"	21'2"	22'6"
2011	19'3"	19'11"	20'3"	21'8"	26'3"	27'8"

YEAR	APRIL		MAY		JUNE	
	1st test	2nd test	1st test	2nd test	1st test	2nd test
2002	15' 0"	15' 4"	14' 6"	14' 3"	14' 0"	14' 0"
2003	12' 10"	12' 11"	12' 11"	13' 0"	13' 8"	13' 2"
2004	18' 3"	0.00	0.00	0.00	0.00	0.00
2005	23' 9"	25' 2"	20' 3"	20' 0"	17' 9"	16' 5"
2006	24'11"	25'1"	19'10"	19'2"	17'1"	16'3"
2007	24'1"	24'10"	20'1"	18'11"	16'9"	15'11"
2008	24'3"	25'2"	20'2"	19'8"	16'7"	16'1"
2009	24'3"	25'3"	20'11"	19'1"	18'5"	17'7"
2010	23'3"	24'0"	22'0"	20'3"	19'6"	18'2"
2011	25'7"	25'4"	21'7"	21'0"	17'2"	16'1"

YEAR	OCTOBER		NOVEMBER		DECEMBER	
	1st test	2nd test	1st test	2nd test	1st test	2nd test
2002	10' 0"	10' 4"	10' 6"	10' 8"	10' 8"	10' 9"
2003	10' 9"	10' 4"	10' 6"	10' 8"	11' 3"	13' 5"
2004	6' 7"	6' 3"	7' 7"	8' 3"	8' 7"	9' 3"
2005	7'7"	8'2"	9'6"	10'8"	11'4"	12'4"
2006	8'7"	9'3"	9'10"	10'5"	11'0"	11'9"
2007	5'1"	6'3"	8'1"	10'3"	11'0"	11'7"
2008	6'9"	7'6"	8'7"	10'5"	12'3"	13'1"
2009	11'8"	12'2"	12'7"	13'4"	14'10"	15'9"
2010	12'0"	12'7"	13'9"	14'8"	14'10"	16'2"
2011	9'9"	9'8"	12'8"	13'6"	14'5"	15'9"

YEAR	OCTOBER		NOVEMBER		DECEMBER	
	1st test	2nd test	1st test	2nd test	1st test	2nd test
2002	10' 0"	10' 4"	10' 6"	10' 8"	10' 8"	10' 9"
2003	10' 9"	10' 4"	10' 6"	10' 8"	11' 3"	13' 5"
2004	6' 7"	6' 3"	7' 7"	8' 3"	8' 7"	9' 3"
2005	7'7"	8'2"	9'6"	10'8"	11'4"	12'4"
2006	8'7"	9'3"	9'10"	10'5"	11'0"	11'9"
2007	5'1"	6'3"	8'1"	10'3"	11'0"	11'7"
2008	6'9"	7'6"	8'7"	10'5"	12'3"	13'1"
2009	11'8"	12'2"	12'7"	13'4"	14'10"	15'9"
2010	12'0"	12'7"	13'9"	14'8"	14'10"	16'2"
2011	9'9"	9'8"	12'8"	13'6"	14'5"	15'9"

Table 1.6 Groundwater level at Noyalavanga union of Shibganj Upazila

YEAR	JANUARY		FEBRUARY		MARCH	
	1st test	2nd test	1st test	2nd test	1st test	2nd test
2002	13' 10"	13' 8"	14' 6"	15' 0"	17' 10"	19' 8"
2003	15' 2"	16' 8"	17' 4"	18' 2"	18' 3"	18' 5"
2004	13' 3"	14' 1"	15' 8"	19' 2"	22' 2"	22' 3"
2005	14' 6"	14' 9"	15' 9"	20' 2"	20' 6"	21' 9"
2006	15'3"	15'11"	17'2"	20'0"	20'6"	22'2"
2007	13'4"	14'3"	15'8"	17'2"	19'4"	21'11"
2008	13'8"	14'6"	15'5"	17'1"	19'2"	21'10"
2009	15'5"	16'2"	17'4"	19'7"	19'6"	21'11"
2010	18'3"	19'1"	21'3"	24'2"	25'6"	26'5"
2011	19'8"	20'6"	22'3"	25'2"	26'3"	27'8"

YEAR	APRIL		MAY		JUNE	
	1st test	2nd test	1st test	2nd test	1st test	2nd test
2002	19' 4"	18' 0"	17' 9"	17' 2"	17' 0"	16' 6"
2003	18' 8"	18' 10"	18' 10"	19' 0"	18' 11"	18' 4"
2004	21' 9"	21' 2"	20' 9"	20' 5"	18' 9"	18' 2"
2005	25' 9"	27' 2"	21' 9"	20' 2"	17' 2"	16' 9"
2006	26'1"	26'11"	21'4"	19'8"	16'9"	16'1"
2007	23'8"	25'5"	21'3"	19'6"	16'4"	15'7"
2008	23'11"	25'7"	21'1"	20'6"	16'8"	15'9"
2009	23'2"	23'6"	21'11"	20'7"	18'8"	17'2"
2010	27'0"	27'6"	25'4"	23'6"	21'4"	18'4"
2011	25'8"	25'5"	21'8"	21'2"	18'2"	16'1"

YEAR	JULY		AUGUST		SEPTEMBER	
	1st test	2nd test	1st test	2nd test	1st test	2nd test
2002	16' 3"	16' 1"	13' 6"	11' 4"	12' 0"	7' 6"
2003	16' 2"	16' 1"	13' 6"	12' 5"	9' 8"	8' 0"
2004	12' 1"	10' 4"	10' 6"	10' 0"	9' 5"	9' 0"
2005	12' 6"	10' 0"	7'6"	7'0"	9'0"	9'9"
2006	11'10"	9'9"	8'6"	8'1"	8'4"	8'0"
2007	11'8"	9'7"	8'3"	7'2"	6'10"	6'6"
2008	11'7"	9'5"	8'5"	7'4"	6'4"	6'2"
2009	13'2"	13'3"	12'3"	11'2"	10'11"	11'4"
2010	16'6"	14'6"	13'6"	12'6"	11'6"	11'1"
2011	16'0"	14'1"	11'5"	11'2"	10'8"	10'6"

YEAR	OCTOBER		NOVEMBER		DECEMBER	
	1st test	2nd test	1st test	2nd test	1st test	2nd test
2002	8' 0"	8' 6"	9' 9"	10' 0"	10' 2"	10' 5"
2003	9' 8"	9' 10"	10' 8"	11' 5"	12' 2"	12' 8"
2004	7' 0"	6' 1"	7' 3"	8' 6"	8' 0"	9' 6"
2005	9'2"	8'2"	8'11"	9'4"	11'3"	14'9"
2006	9'4"	10'2"	10'8"	11'3"	11'10"	12'6"
2007	7'20"	8'9"	9'10"	11'1"	11'10"	12'5"
2008	6'8"	7'0'	9'8"	11'5"	12'2"	13'8"
2009	11'6"	11'11"	13'3"	14'0"	14'10"	15'9"
2010	12'2"	13'8"	14'2"	14'10"	146'8"	17'6"
2011	10'7"	10'5"	13'8"	14'2"	16'4"	17'2"

Table 1.7 Groundwater level at Bholahat union of Bholahat Upazila

YEAR	JANUARY		FEBRUARY		MARCH	
	1st test	2nd test	1st test	2nd test	1st test	2nd test
2002	17' 2"	19' 6"	20' 3"	24' 11"	27' 5"	29' 9"
2003	14' 9"	17' 4"	20' 0"	24' 8"	25' 0"	26' 8"
2004	24' 0"	24' 7"	35' 0"	35' 6"	40' 4"	40' 10"
2005	21' 2"	21' 10"	36' 5"	37' 9"	38' 3"	29' 9"
2006	20'11"	21'11"	23'10"	25'8"	26'11"	28'1"
2007	30'2"	32'4"	33'2"	34'1"	35'2"	36'1"
2008	29'1"	30'5"	32'4"	34'2"	37'2"	40'1"
2009	27'2"	32'7"	35'1"	37'4"	36'1"	32'2"
2010	30'4"	30'6"	39'4"	39'7"	41'6"	43'0"
2011	22'3"	23'2"	37'1"	39'9"	41'3"	44'10"

YEAR	APRIL		MAY		JUNE	
	1st test	2nd test	1st test	2nd test	1st test	2nd test
2002	22' 3"	21' 1"	17' 8"	16' 5"	15' 9"	14' 8"
2003	26' 1"	27' 5"	19' 9"	21' 4"	15' 4"	17' 3"
2004	25' 0"	25' 5"	18' 10"	18' 0"	17' 6"	17' 0"
2005	30'5"	32'8"	24' 6"	26' 3"	36' 9"	38' 2"
2006	28'5"	30'3"	29'9"	28'1"	26'9"	25'8"
2007	36'5"	37'2"	37'0"	36'2"	34'1"	32'3"
2008	42'3"	44'2"	50'1"	49'4"	42'4"	38'1"
2009	36'1"	35'2"	27'2"	20'4"	24'9"	28'2"
2010	41'9"	40'6"	34'11"	27'10"	24'11"	18'8"
2011	41'11"	40'9"	36'8"	32'0"	28'8"	24'0"

YEAR	JULY		AUGUST		SEPTEMBER	
	1st test	2nd test	1st test	2nd test	1st test	2nd test
2002	14' 3"	13' 11"	9' 3"	7' 1"	6' 11"	6' 3"
2003	14' 2"	15' 5"	10' 5"	10' 0"	9' 5"	9' 0"
2004	12' 6"	12' 0"	10' 5"	10' 0"	9' 6"	9' 2"
2005	25' 0"	24' 4"	18'3"	15'6"	15'3"	15'0"
2006	25'1"	24'3"	24'0"	22'2"	21'1"	19'5"
2007	30'0"	27'5"	25'9"	23'10"	23'0"	22'2"
2008	35'2"	33'4"	31'3"	29'2"	13'9"	12'2"
2009	24'9"	21'0"	16'6"	12'8"	12'4"	11'9"
2010	17'1"	16'4"	16'0"	15'8"	14'7"	14'3"
2011	22'1"	19'8"	15'7"	12'1"	12'7"	11'8"

YEAR	OCTOBER		NOVEMBER		DECEMBER	
	1st test	2nd test	1st test	2nd test	1st test	2nd test
2002	6' 11"	6' 3"	8' 0"	8' 7"	12' 0"	12' 9"
2003	8' 0"	8' 0"	13' 0"	13' 5"	15' 0"	15' 4"
2004	10'0"	10'6"	15'8"	16'6"	16'4"	16'3"
2005	13'2"	11'9"	12'2"	13'0"	14'0"	15'2"
2006	19'1"	22'6"	24'2"	26'4"	27'1"	28'2"
2007	21'8"	22'6"	23'5"	24'2"	25'9"	27'1"
2008	12'4"	12'6"	14'2"	16'9"	18'2"	19'5"
2009	15'4"	19'7"	23'4"	23'10"	28'6"	30'3"
2010	21'4"	25'1"	23'5"	21'2"	21'9"	22'1"
2011	13'1"	15'8"	16'9"	17'2"	23"1"	25'8"

Table 1.8 Groundwater level at Gohaeelbari union of Bholahat Upazila

YEAR	JANUARY		FEBRUARY		MARCH	
	1st test	2nd test	1st test	2nd test	1st test	2nd test
2002	25' 6"	27' 9"	33' 9"	36' 11"	43' 3"	45' 5"
2003	24' 7"	26' 1"	40' 9"	43' 0"	44' 0"	45' 2"
2004	33' 0"	33' 5"	45' 0"	45' 4"	50' 4"	52' 7"
2005	26' 3"	27' 8"	34' 4"	36' 7"	37' 4"	30' 3"
2006	25'5"	26'7"	35'10"	37'2"	38'1"	39'2"
2007	33'4"	35'2"	37'1"	38'2"	39'3"	40'2"
2008	32'5"	33'4"	35'7"	37'2"	39'3"	41'4"
2009	31'3"	37'4"	50'3"	55'8"	59'2"	62'8"
2010	36'11"	37'1"	53'7"	57'7"	58'11"	60'11"
2011	33'9"	34'1"	49'11"	56'0"	59'9"	62'11"

YEAR	APRIL		MAY		JUNE	
	1st test	2nd test	1st test	2nd test	1st test	2nd test
2002	39' 11"	38' 2"	37' 9"	36' 5"	35' 2"	33' 9"
2003	47' 0"	48' 3"	27' 2"	28' 6"	23' 2"	25' 6"
2004	46' 0"	46' 5"	33' 9"	33' 0"	32' 5"	32' 0"
2005	35'8"	39'6"	31' 4"	33' 5"	45' 4"	47' 3"
2006	40'8"	42'6"	40'6"	39'0"	38'1"	37'0"
2007	40'9"	41'4"	40'2"	39'3"	38'1"	37'2"
2008	45'2"	48'3"	50'1"	49'4"	47'2"	44'2"
2009	60'2"	59'9"	50'4"	42'3"	44'8"	46'2"
2010	60'0"	59'4"	49'10"	42'11"	38'4"	27'10"
2011	59'2"	58'10"	51'8"	42'7"	32'11"	28'8"

YEAR	JULY		AUGUST		SEPTEMBER	
	1st test	2nd test	1st test	2nd test	1st test	2nd test
2002	31' 4"	30' 0"	26' 5"	19' 6"	19' 1"	18' 0"
2003	21' 1"	23' 4"	20' 5"	20' 0"	15' 6"	15' 0"
2004	22' 5"	22' 0"	19' 6"	19' 0"	17' 8"	17' 1"
2005	31' 8"	31' 0"	24'5"	22'9"	22'6"	22'0"
2006	35'5"	34'0"	32'8"	29'1"	29'0"	28'7"
2007	34'3"	31'2"	29'3"	27'1"	26'8"	25'11"
2008	41'3"	38'4"	35'8"	34'1"	28'9"	26'4"
2009	44'5"	41'2"	34'2"	27'10"	26'8"	25'7"
2010	25'11"	23'8"	22'2"	21'9"	21'3"	20'9"
2011	26'9"	23'11"	21'3"	19'8"	20'9"	20'8"

YEAR	OCTOBER		NOVEMBER		DECEMBER	
	1st test	2nd test	1st test	2nd test	1st test	2nd test
2002	16' 6"	21' 4"	16' 4"	21' 7"	21' 0"	21' 4"
2003	15' 0"	15' 0"	19' 0"	19' 5"	21' 0"	21' 4"
2004	18'0"	18'02"	17'6"	16'5"	17'5"	17'3"
2005	19'4"	18'0"	18'3"	19'1"	24'3"	28'6"
2006	28'6"	28'4"	28'3"	29'11"	30'5"	31'1"
2007	25'2"	26'9"	27'5"	28'11"	30'1"	31'2"
2008	26'6"	268"	27'7"	28'9"	29'2"	29'3"
2009	30'2"	34'10"	35'8"	35'11"	36'3"	36'10"
2010	28'11"	32'6"	32'9"	33'1"	33'2"	33'6"
2011	24'2"	29'6"	27'3"	26'10"	27'9"	28'2"

Table 1.9 Groundwater level at Boalia union of Gomastapur Upazila

YEAR	JANUARY		FEBRUARY		MARCH	
	1st test	2nd test	1st test	2nd test	1st test	2nd test
2002	10' 8"	10' 11"	25' 9"	26' 0"	26' 3"	26' 5"
2003	16' 2"	17' 9"	19' 8"	22' 6"	22' 11"	24' 6"
2004	10' 11"	11' 5"	16' 3"	16' 11"	17' 10"	18' 8"
2005	15' 11"	16' 2"	16' 4"	16' 7"	21' 3"	20' 2"
2006	20'11"	21'0"	21'2"	21'6"	21'9"	22'0"
2007	19'1"	19'3"	19'4"	19'6"	19'9"	20'0"
2008	21'6"	21'11"	21'8"	21'11"	21'10"	22'6"
2009	20'3"	20'9"	27'10"	32'3"	38'10"	39'6"
2010	20'3'"	20'6"	28'10"	34'1"	34'11"	36'8"
2011	21'7"	21'11"	207"	21'11"	30'6"	31'8"

YEAR	APRIL		MAY		JUNE	
	1st test	2nd test	1st test	2nd test	1st test	2nd test
2002	26' 3"	22' 2"	19' 8"	19' 6"	18' 11"	17' 10"
2003	22' 11"	24' 6"	21' 6"	21' 1"	21' 1"	19' 8"
2004	19' 0"	18' 5"	18' 2"	17' 8"	17' 6"	17' 6"
2005	20' 0"	19' 9"	20' 6"	20' 10"	19' 4"	19' 0"
2006	20'8"	20'2"	19'6"	19'1"	18'11"	18'9"
2007	20'1"	20'1"	19'11"	20'2"	19'7"	19'3"
2008	22'10"	22'11"	20'6"	20'9"	18'0"	17'6"
2009	41'0"	40'9"	39'0"	37'11"	36'2"	32'5"
2010	33'5"	30'11"	29'11"	29'2"	29'2"	29'0"
2011	28'10"	27'5"	28'7"	28'2"	28'0"	27'9"

YEAR	JULY		AUGUST		SEPTEMBER	
	1st test	2nd test	1st test	2nd test	1st test	2nd test
2002	17' 6"	26' 11"	10' 11"	7' 1"	6' 4"	5' 6"
2003	19' 3"	18' 8"	18' 1"	17' 10"	15' 9"	14' 3"
2004	16' 11"	16' 5"	14' 7"	12' 9"	14' 2"	13' 4"
2005	18' 10"	18' 2"	19'8"	20'8"	20'10"	21'4"
2006	18'5"	18'3"	17'9"	17'3"	17'0"	16'8"
2007	18'6"	18'2"	17'7"	17'5"	17'0"	17'2"
2008	17'9"	17'7"	17'7"	17'4"	17'10"	18'0"
2009	27'9"	24'7"	21'7"	19'4"	18'8"	19'3"
2010	26'7"	23'9"	19'11"	17'8"	18'5"	17'3"
2011	24'5"	23'3"	12'9"	11'6"	10'11"	8'2"

YEAR	OCTOBER		NOVEMBER		DECEMBER	
	1st test	2nd test	1st test	2nd test	1st test	2nd test
2002	7' 3"	8' 6"	10' 5"	13' 4"	14' 5"	15' 8"
2003	10' 6"	8' 1"	8' 5"	8' 11"	9' 4"	10' 2"
2004	14' 0"	14' 2"	14' 9"	15' 3"	15' 6"	15' 9"
2005	20'6"	20'4"	20'7"	20'8"	20'8"	20'10"
2006	16'10"	17'1"	18'2"	18'4"	18'9"	18'11"
2007	18'3"	18'0"	18'5"	18'7"	21'10"	21'10"
2008	17'11"	18'6"	18'8"	19'0"	19'1"	19'3"
2009	19'7"	19'11"	19'2"	20'7"	20'1"	20'4"
2010	18'8"	19'4"	20'3"	20'9"	20'8"	21'4"
2011	11'4"	12'6"	14'9"	15'2"	17'8"	18'5"

Table 1.10 Groundwater level at Gomastapur union of Gomastapur Upazila

YEAR	JANUARY		FEBRUARY		MARCH	
	1st test	2nd test	1st test	2nd test	1st test	2nd test
2002	42' 6"	42' 9"	52' 1"	52' 7"	54' 3"	54' 4"
2003	43' 4"	44' 6"	47' 6"	50' 4"	51' 9"	53' 6"
2004	42' 8"	43' 1"	47' 0"	48' 1"	49' 3"	50' 2"
2005	44' 3"	44' 5"	44' 8"	44' 11"	51' 2"	50' 3"
2006	50'6"	50'7"	51'4"	51'6"	51'8"	51'11"
2007	51'3"	51'6"	51'7"	51'9"	52'1"	52'3"
2008	50'5"	50'9"	51'6"	51'8"	51'9"	52'0"
2009	53'3"	54'0"	59'5"	61'3"	65'9"	66'10"
2010	54'1"	54'10"	51'9"	64'7"	66'3"	67'10"
2011	56'9"	57'1"	54'9"	55'1"	44'7"	57'1"

YEAR	APRIL		MAY		JUNE	
	1st test	2nd test	1st test	2nd test	1st test	2nd test
2002	54' 2"	54' 4"	53' 10"	52' 11"	52' 7"	50' 9"
2003	51' 9"	53' 6"	51' 0"	50' 2"	50' 0"	49' 1"
2004	50' 6"	50' 1"	49' 1"	48' 3"	48' 1"	47' 10"
2005	50' 0"	49' 9"	51' 6"	42' 0"	50' 8"	50' 0"
2006	50'6"	50'0"	48'10"	48'6"	48'4"	48'2"
2007	52'4"	52'6"	52'3"	52'7"	52'0"	51'9"
2008	52'3"	52'6"	51'9"	52'3"	48'8"	48'2"
2009	66'11"	66'9"	51'7"	50'6"	49'3"	48'4"
2010	66'8"	64'7"	64'3"	62'2"	60'3"	68'0"
2011	66'7"	61'6"	62'7"	65'8"	64'5"	54'5"

YEAR	JULY		AUGUST		SEPTEMBER	
	1st test	2nd test	1st test	2nd test	1st test	2nd test
2002	50' 3"	49' 10"	46' 6"	46' 10"	46' 8"	46' 6"
2003	49' 0"	48' 6"	48' 2"	47' 9"	45' 9"	43' 6"
2004	46' 1"	45' 3"	44' 9"	44' 4"	43' 2"	42' 4"
2005	49' 0"	48' 8"	49'6"	49'10"	50'3"	50'11"
2006	47'7"	47'2"	46'6"	46'0"	45'8"	45'1"
2007	50'10"	50'3"	49'2"	49'0"	48'5"	48'1"
2008	47'5"	47'1"	45'6"	45'3"	45'7"	45'9"
2009	45'5"	42'1"	45'6"	45'3"	46'4"	47'2"
2010	41'8"	39'2"	43'4"	42'9"	52'9"	51'7"
2011	53'3"	52'9"	57'4"	56'11"	54'7"	49'1"

YEAR	OCTOBER		NOVEMBER		DECEMBER	
	1st test	2nd test	1st test	2nd test	1st test	2nd test
2002	41' 2"	42' 1"	41' 2"	42' 6"	42' 3"	42' 11"
2003	41' 5"	39' 1"	39' 6"	41' 0"	41' 9"	42' 1"
2004	42' 6"	42' 8"	43' 0"	43' 4"	43' 8"	44' 1"
2005	50'0"	50'3"	50'2"	50'3"	50'4"	50'5"
2006	50'3"	50'5"	50'6"	50'7"	50'10"	51'0"
2007	49'3"	49'0"	49'5"	49'7"	50'3"	50'7"
2008	48'9"	50'3"	50'8"	51'3"	51'5"	51'6"
2009	47'5"	47'10"	51'6"	52'2"	53'9"	53'11"
2010	52'2"	52'7"	55'9"	56'2"	56'2"	56'5"
2011	55'5"	55'11"	56'2"	56'8"	52'4"	51'7"

Appendix-2:

Rainfall data of five Upazilas at Chapai Nawabganj District

Table 2.1 Rainfall data of five Upazilas at Chapai Nawabganj district in 2002

ZONE/DATE	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02	Nov-02	Dec-02	Total
Nawabgonj	3.00	4.00	8.60	104.80	112.20	186.20	246.50	378.60	393.00	58.60	7.00	0.00	1502.50
Shibgonj	12.00	1.00	10.00	76.00	126.00	200.00	232.00	263.50	361.50	78.00	5.00	0.00	1365.00
Gomostapur	0.00	0.00	0.00	106.00	101.00	122.00	136.00	263.00	208.00	30.00	8.00	0.00	974.00
Nachol	10.00	21.00	35.00	69.00	278.00	181.00	189.00	355.00	344.00	34.00	416.00	0.00	1932.00
Bholahat	0.00	0.00	8.00	148.27	141.20	88.56	127.26	267.02	290.54	50.58	9.51	0.00	1130.94
Nawab. Avg.	**5.00**	**5.20**	**12.32**	**100.81**	**151.68**	**155.55**	**186.15**	**305.42**	**319.41**	**50.24**	**89.10**	**0.00**	**1380.89**

Table 2.2 Rainfall data of five Upazilas at Chapai Nawabganj district in 2003

ZONE/DATE	Jan-03	Feb-03	Mar-03	Apr-03	May-03	Jun-03	Jul-03	Aug-03	Sep-03	Oct-03	Nov-03	Dec-03	Total
Nawabgonj	2.00	53.00	62.00	14.90	54.00	332.54	190.00	77.01	115.00	175.00	0.00	7.00	1082.45
Shibgonj	0.00	43.00	29.00	32.00	92.00	185.00	19.00	38.00	161.00	201.00	0.00	9.00	809.00
Gomostapur	0.00	50.00	38.00	30.00	65.00	261.00	240.00	118.00	242.00	204.00	0.00	8.00	1256.00
Nachol	0.00	83.00	36.00	35.00	78.00	335.48	381.00	204.00	223.00	215.00	0.00	1.27	1591.75
Bholahat	0.00	65.20	29.73	25.70	138.58	277.10	137.24	63.81	183.83	174.89	0.00	41.00	1137.08
Nawab. Avg.	**0.40**	**58.84**	**38.95**	**27.52**	**85.52**	**278.22**	**193.45**	**100.16**	**184.97**	**193.98**	**0.00**	**13.25**	**1175.26**

Units: All the Rainfall data in mm

Table 2.3 Rainfall data of five Upazilas at Chapai Nawabganj district in 2004

ZONE/DATE	Jan-04	Feb-04	Mar-04	Apr-04	May-04	Jun-04	Jul-04	Aug-04	Sep-04	Oct-04	Nov-04	Dec-04	Total
Nawabgonj	28.84	12.00	1.10	72.50	68.00	310.02	210.00	155.00	230.00	441.40	0.00	0.00	1528.86
Shibgonj	7.00	0.00	1.00	32.00	78.00	231.00	225.00	158.00	155.00	408.00	0.00	0.00	1295.00
Gomostapur	23.00	0.00	0.00	97.00	115.00	375.00	304.00	229.00	206.00	468.00	0.00	0.00	1817.00
Nachol	10.00	0.00	0.00	67.00	69.00	323.00	283.00	140.00	0.00	295.00	0.00	0.00	1187.00
Bholahat	25.57	0.00	0.00	130.60	60.32	326.83	309.23	232.88	174.37	685.52	0.00	0.00	1945.32
Nawab. Avg.	**18.88**	**2.40**	**0.42**	**79.82**	**78.06**	**313.17**	**266.25**	**182.98**	**153.07**	**459.58**	**0.00**	**0.00**	**1554.64**

Units : All the Rainfall data in mm

Table 2.4 Rainfall data of five Upazilas at Chapai Nawabganj district in 2005

ZONE/DATE	Jan-05	Feb-05	Mar-05	Apr-05	May-05	Jun-05	Jul-05	Aug-05	Sep-05	Oct-05	Nov-05	Dec-05	Total
Nawabgonj	0.00	0.00	25.00	68.00	72.00	70.00	460.00	390.00	101.00	275.00	0.00	0.00	1461.00
Shibgonj	7.00	1.00	55.00	24.00	32.00	192.00	464.00	382.00	155.00	189.00	0.00	0.00	1501.00
Gomostapur	12.00	11.00	35.00	32.00	78.00	101.00	483.00	253.00	95.00	244.00	0.00	0.00	1344.00
Nachol	0.00	0.00	91.00	81.00	68.00	84.00	240.00	209.00	137.00	231.00	0.00	0.00	1141.00
Bholahat	9.36	0.00	57.23	91.25	31.63	32.85	777.81	215.28	127.02	116.61	0.00	0.00	1459.04
Nawab. Avg.	**5.67**	**2.40**	**52.65**	**59.25**	**56.33**	**95.97**	**484.96**	**289.86**	**123.00**	**211.12**	**0.00**	**0.00**	**1381.21**

Table 2.5 Rainfall data of five Upazilas at Chapai Nawabganj district in 2006

ZONE/DATE	Jan-06	Feb-06	Mar-06	Apr-06	May-06	Jun-06	Jul-06	Aug-06	Sep-06	Oct-06	Nov-06	Dec-06	Total
Nawabgonj	0.00	0.00	43.00	65.00	333.00	303.00	322.00	277.50	293.00	41.00	17.00	0.00	1694.50
Shibgonj	0.00	0.00	24.00	59.00	284.00	377.00	294.00	393.00	349.00	8.00	32.00	0.00	1820.00
Gomostapur	0.00	0.00	39.00	33.00	43.00	99.00	216.00	245.00	298.00	17.00	0.00	0.00	990.00
Nachol	0.00	0.00	41.00	92.00	63.00	661.00	277.00	226.00	247.00	9.00	0.00	0.00	1616.00
Bholahat	0.00	0.00	26.32	83.00	167.00	197.00	228.00	264.00	451.00	60.00	12.00	0.00	1488.32
Nawab. Avg.	**0.00**	**0.00**	**34.66**	**66.40**	**178.00**	**327.40**	**267.40**	**281.10**	**327.60**	**27.00**	**12.20**	**0.00**	**1521.76**

Table 2.6 Rainfall data of five Upazilas at Chapai Nawabganj district in 2007

ZONE/DATE	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
Nawabgonj	0.00	20.00	35.00	17.00	148.00	268.00	716.00	298.00	386.00	76.00	0.00	0.00	1964.00
Shibgonj	0.00	23.00	48.00	13.00	53.00	314.00	901.00	272.00	240.00	46.00	0.00	0.00	1910.00
Gomostapur	0.00	20.00	33.00	0.00	38.00	252.00	494.00	155.00	289.00	60.00	0.00	0.00	1341.00
Nachol	0.00	3.00	35.00	0.00	275.00	219.50	645.00	372.50	409.00	70.00	0.00	0.00	2029.00
Bholahat	0.00	63.12	43.39	0.00	63.00	362.50	699.00	162.00	264.00	65.00	0.00	0.00	1722.01
Nawab. Avg.	**0.00**	**25.82**	**38.88**	**6.00**	**115.40**	**283.20**	**691.00**	**251.90**	**317.60**	**63.40**	**0.00**	**0.00**	**1793.20**

Table 2.7 Rainfall data of five Upazilas at Chapai Nawabganj district in 2008

ZONE/DATE	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08	Sep-08	Oct-08	Nov-08	Dec-08	Total
Nawabgonj	34.00	0.00	10.00	21.00	110.00	414.00	293.00	167.00	193.00	60.00	0.00	0.00	1302.00
Shibgonj	25.00	0.00	5.00	46.30	26.00	506.00	382.00	199.00	231.00	104.00	0.00	0.00	1524.30
Gomostapur	62.00	5.00	32.00	5.00	139.00	303.00	197.00	162.00	166.00	76.00	0.00	0.00	1147.00
Nachol	0.00	0.00	55.00	0.00	16.00	358.90	367.00	188.70	191.00	18.50	0.00	0.00	1195.10
Bholahat	85.20	0.00	11.44	4.16	71.73	337.11	192.33	264.38	131.92	3.00	0.00	0.00	1101.27
Nawab. Avg.	**41.24**	**1.00**	**22.69**	**15.29**	**72.55**	**383.80**	**286.27**	**196.22**	**182.58**	**52.30**	**0.00**	**0.00**	**1253.93**

Table 2.8 Rainfall data of five Upazilas at Chapai Nawabganj district in 2009

ZONE/DATE	Jan-09	Feb-09	Mar-09	Apr-09	May-09	Jun-09	Jul-09	Aug-09	Sep-09	Oct-09	Nov-09	Dec-09	Total
Nawabgonj	0.00	18.00	22.00	0.00	238.00	20.00	115.00	207.0	258.00	64.00	4.00	0.00	946.00
Shibgonj	0.00	22.00	19.00	0.00	229.00	23.00	208.00	210.0	333.00	55.00	0.00	0.00	1099.00
Gomostapur	0.00	0.00	14.00	6.00	227.00	46.00	259.0	271.0	259.00	242.00	0.00	0.00	1324.00
Nachol	0.00	5.00	0.00	0.00	231.50	18.00	273.5	383.0	210.00	107.00	0.00	0.00	1228.00
Bholahat	0.00	39.00	0.00	0.00	273.92	63.28	268.9	244.6	123.12	184.92	2.00	0.00	1199.74
Nawab. Avg.	**0.00**	**16.80**	**11.00**	**1.20**	**239.88**	**34.06**	**224.88**	**263.12**	**236.62**	**130.58**	**1.20**	**0.00**	**1159.35**

Table 2.9 Rainfall data of five Upazilas at Chapai Nawabganj district in 2010

ZONE/DATE	Jan-10	Feb-10	Mar-10	Apr-10	May-10	Jun-10	Jul-10	Aug-10	Sep-10	Oct-10	Nov-10	Dec-10	Total
Nawabgonj	0.00	5.00	9.00	58.00	101.00	176.00	292.00	100.0	140.00	78.00	4.00	8.00	971.00
Shibgonj	0.00	0.00	19.00	67.00	97.00	220.00	145.00	98.0	228.00	150.00	0.00	0.00	1024.00
Gomostapur	0.00	0.00	6.00	20.00	190.00	374.00	140.0	321.0	74.00	113.00	10.00	0.00	1248.00
Nachol	0.00	0.00	10.00	25.00	145.00	219.00	202.0	150.0	157.00	74.00	0.00	5.00	987.00
Bholahat	0.00	2.50	0.00	17.00	139.36	195.92	185.5	163.3	97.16	80.00	11.00	5.00	896.70
Nawab. Avg.	**0.00**	**1.50**	**8.80**	**37.40**	**134.47**	**236.98**	**192.90**	**166.46**	**139.23**	**99.00**	**5.00**	**3.60**	**1025.34**

Table 2.10 Rainfall data of five Upazilas at Chapai Nawabganj district in 2011

ZONE/DATE	Jan-11	Feb-11	Mar-11	Apr-11	May-11	Jun-11	Jul-11	Aug-11	Sep-11	Oct-11	Nov-11	Dec-11	Total
Nawabgonj	1.00	0.00	61.00	88.00	103.00	484.00	81.50	283.0	180.00	32.00	0.00	0.00	1313.50
Shibgonj	0.00	0.00	76.00	105.00	207.00	495.00	141.00	615.0	151.00	0.00	0.00	0.00	1790.00
Gomostapur	0.00	5.00	5.00	60.00	163.00	489.00	156.0	312.0	361.00	0.00	0.00	0.00	1551.00
Nachol	0.00	0.00	7.00	68.00	213.00	502.00	35.00	368.0	303.00	0.00	0.00	0.00	1496.00
Bholahat	0.00	0.00	4.00	31.00	126.00	345.00	201.0	445.0	386.00	60.00	0.00	0.00	1598.00
Nawab. Avg.	**0.20**	**1.00**	**30.60**	**70.40**	**162.40**	**463.00**	**122.90**	**404.60**	**276.20**	**18.40**	**0.00**	**0.00**	**1549.70**

Appendix-3

Table 3.1 Evapotranspiration data of Chapai Nawabganj district.

2002					
Date and Time	ET Value	Date and Time	ET Value	Date and Time	ET Value
1/1/2002 9:00	2	2/11/2002 9:00	2	3/24/2002 9:00	2
1/2/2002 9:00	2	2/12/2002 9:00	7	3/25/2002 9:00	2
1/3/2002 9:00	2	2/13/2002 9:00	2	3/26/2002 9:00	2
1/4/2002 9:00	2	2/14/2002 9:00	2	3/27/2002 9:00	2
1/5/2002 9:00	2	2/15/2002 9:00	2	3/28/2002 9:00	2
1/6/2002 9:00	2	2/16/2002 9:00	2	3/29/2002 9:00	2
1/7/2002 9:00	2	2/17/2002 9:00	2	3/30/2002 9:00	2
1/8/2002 9:00	2	2/18/2002 9:00	2	3/31/2002 9:00	7
1/9/2002 9:00	2	2/19/2002 9:00	2	3/31/2002 9:00	7
1/10/2002 9:00	2	2/20/2002 9:00	7	4/1/2002 9:00	2
1/11/2002 9:00	2	2/21/2002 9:00	2	4/2/2002 9:00	2
1/12/2002 9:00	2	2/22/2002 9:00	2	4/3/2002 9:00	2
1/13/2002 9:00	2	2/23/2002 9:00	2	4/4/2002 9:00	2
1/14/2002 9:00	2	2/24/2002 9:00	2	4/5/2002 9:00	2
1/15/2002 9:00	2	2/25/2002 9:00	2	4/6/2002 9:00	2
1/16/2002 9:00	2	2/26/2002 9:00	2	4/7/2002 9:00	2
1/17/2002 9:00	2	2/27/2002 9:00	2	4/8/2002 9:00	2
1/18/2002 9:00	2	2/28/2002 9:00	2	4/9/2002 9:00	2
1/19/2002 9:00	2	3/1/2002 9:00	2	4/10/2002 9:00	2
1/20/2002 9:00	2	3/2/2002 9:00	2	4/11/2002 9:00	2
1/21/2002 9:00	2	3/3/2002 9:00	2	4/12/2002 9:00	2
1/22/2002 9:00	2	3/4/2002 9:00	2	4/13/2002 9:00	2
1/23/2002 9:00	2	3/5/2002 9:00	2	4/14/2002 9:00	2
1/24/2002 9:00	2	3/6/2002 9:00	2	4/15/2002 9:00	2
1/25/2002 9:00	2	3/7/2002 9:00	2	4/16/2002 9:00	2
1/26/2002 9:00	2	3/8/2002 9:00	2	4/17/2002 9:00	2
1/27/2002 9:00	2	3/9/2002 9:00	2	4/18/2002 9:00	2
1/28/2002 9:00	2	3/10/2002 9:00	2	4/19/2002 9:00	2
1/29/2002 9:00	2	3/11/2002 9:00	2	4/20/2002 9:00	2
1/30/2002 9:00	2	3/12/2002 9:00	7	4/21/2002 9:00	2
1/31/2002 9:00	2	3/13/2002 9:00	7	4/22/2002 9:00	2
2/1/2002 9:00	2	3/14/2002 9:00	2	4/23/2002 9:00	2
2/2/2002 9:00	2.5	3/15/2002 9:00	2	4/24/2002 9:00	6.3
2/3/2002 9:00	2	3/16/2002 9:00	2	4/25/2002 9:00	7
2/4/2002 9:00	2	3/17/2002 9:00	2	4/26/2002 9:00	4.5
2/5/2002 9:00	2	3/18/2002 9:00	2	4/27/2002 9:00	2
2/6/2002 9:00	7	3/19/2002 9:00	2	4/28/2002 9:00	2
2/7/2002 9:00	2	3/20/2002 9:00	2	4/29/2002 9:00	2
2/8/2002 9:00	2	3/21/2002 9:00	2	4/30/2002 9:00	2
2/9/2002 9:00	2	3/22/2002 9:00	2	5/1/2002 9:00	2
2/10/2002 9:00	2	3/23/2002 9:00	2	5/2/2002 9:00	3

Units: All the Evapotranspiration data in mm

Date and Time	ET Value	Date and Time	ET Value	Date and Time	ET Value
5/3/2002 9:00	2	6/13/2002 9:00	2	7/24/2002 9:00	2
5/4/2002 9:00	6	6/14/2002 9:00	2	7/25/2002 9:00	2
5/5/2002 9:00	2	6/15/2002 9:00	2	7/26/2002 9:00	2
5/6/2002 9:00	7	6/16/2002 9:00	2	7/27/2002 9:00	2
5/7/2002 9:00	2	6/17/2002 9:00	2	7/28/2002 9:00	2
5/8/2002 9:00	2.5	6/18/2002 9:00	2	7/29/2002 9:00	2
5/9/2002 9:00	2	6/19/2002 9:00	2	7/30/2002 9:00	2
5/10/2002 9:00	2	6/20/2002 9:00	4.7	7/31/2002 9:00	2
5/11/2002 9:00	2	6/21/2002 9:00	7	8/1/2002 9:00	2
5/12/2002 9:00	2	6/22/2002 9:00	7	8/2/2002 9:00	2
5/13/2002 9:00	2	6/23/2002 9:00	7	8/3/2002 9:00	2.5
5/14/2002 9:00	2	6/24/2002 9:00	2	8/4/2002 9:00	7
5/15/2002 9:00	2	6/25/2002 9:00	2	8/5/2002 9:00	2
5/16/2002 9:00	7	6/26/2002 9:00	2	8/6/2002 9:00	5
5/17/2002 9:00	2	6/27/2002 9:00	7	8/7/2002 9:00	7
5/18/2002 9:00	2	6/28/2002 9:00	7	8/8/2002 9:00	2
5/19/2002 9:00	2	6/29/2002 9:00	2	8/9/2002 9:00	2
5/20/2002 9:00	2	6/30/2002 9:00	2	8/10/2002 9:00	2
5/21/2002 9:00	2	7/1/2002 9:00	2	8/11/2002 9:00	2
5/22/2002 9:00	7	7/2/2002 9:00	2	8/12/2002 9:00	7
5/23/2002 9:00	2	7/3/2002 9:00	7	8/13/2002 9:00	2.5
5/24/2002 9:00	2	7/4/2002 9:00	4.7	8/14/2002 9:00	7
5/25/2002 9:00	2	7/5/2002 9:00	7	8/15/2002 9:00	7
5/26/2002 9:00	7	7/6/2002 9:00	5	8/16/2002 9:00	2
5/27/2002 9:00	2	7/7/2002 9:00	7	8/17/2002 9:00	7
5/28/2002 9:00	2	7/8/2002 9:00	7	8/18/2002 9:00	7
5/29/2002 9:00	2	7/9/2002 9:00	3.5	8/19/2002 9:00	2
5/30/2002 9:00	2	7/10/2002 9:00	3	8/20/2002 9:00	2
5/31/2002 9:00	6.5	7/11/2002 9:00	3.1	8/21/2002 9:00	6.5
6/1/2002 9:00	2	7/12/2002 9:00	4.5	8/22/2002 9:00	2
6/2/2002 9:00	2	7/13/2002 9:00	7	8/23/2002 9:00	2
6/3/2002 9:00	2	7/14/2002 9:00	7	8/24/2002 9:00	7
6/4/2002 9:00	2	7/15/2002 9:00	7	8/25/2002 9:00	2
6/5/2002 9:00	2	7/16/2002 9:00	7	8/26/2002 9:00	2
6/6/2002 9:00	2	7/17/2002 9:00	7	8/27/2002 9:00	2
6/7/2002 9:00	2	7/18/2002 9:00	3.5	8/28/2002 9:00	2
6/8/2002 9:00	2	7/19/2002 9:00	3.5	8/29/2002 9:00	7
6/9/2002 9:00	2	7/20/2002 9:00	7	8/30/2002 9:00	2
6/10/2002 9:00	2	7/21/2002 9:00	3.8	8/31/2002 9:00	2
6/11/2002 9:00	2	7/22/2002 9:00	3.6	9/1/2002 9:00	7
6/12/2002 9:00	2	7/23/2002 9:00	2	9/2/2002 9:00	7

Date and Time	ET Value	Date and Time	ET Value	Date and Time	ET Value
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9/5/2002 9.00	2	10/16/2002 9:00	2	11/26/2002 9:00	2
9/6/2002 9.00	2	10/17/2002 9:00	2	11/27/2002 9:00	2
9/7/2002 9.00	2	10/18/2002 9:00	2	11/28/2002 9:00	2
9/8/2002 9.00	2	10/19/2002 9:00	2	11/29/2002 9:00	2
9/9/2002 9.00	2	10/20/2002 9:00	2	11/30/2002 9:00	2
9/10/2002 9.00	2	10/21/2002 9:00	2	12/1/2002 9:00	2
9/11/2002 9.00	7	10/22/2002 9:00	2	12/2/2002 9:00	2
9/12/2002 9.00	2	10/23/2002 9:00	2	12/3/2002 9:00	2
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9/14/2002 9:00	2	10/25/2002 9:00	3	12/5/2002 9:00	2
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9/17/2002 9:00	2	10/28/2002 9:00	2	12/8/2002 9:00	2
9/18/2002 9:00	2	10/29/2002 9:00	2	12/9/2002 9:00	2
9/19/2002 9:00	2	10/30/2002 9:00	2	12/10/2002 9:00	2
9/20/2002 9:00	2	10/31/2002 9:00	2	12/11/2002 9:00	2
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9/22/2002 9:00	7	11/2/2002 9:00	2	12/13/2002 9:00	2
9/23/2002 9:00	2	11/3/2002 9:00	2	12/14/2002 9:00	2
9/24/2002 9:00	2	11/4/2002 9:00	2	12/15/2002 9:00	2
9/25/2002 9:00	7	11/5/2002 9:00	2	12/16/2002 9:00	2
9/26/2002 9:00	7	11/6/2002 9:00	2	12/17/2002 9:00	2
9/27/2002 9:00	2	11/7/2002 9:00	2	12/18/2002 9:00	2
9/28/2002 9:00	2	11/8/2002 9:00	2	12/19/2002 9:00	2
9/29/2002 9:00	2	11/9/2002 9:00	2	12/20/2002 9:00	2
9/30/2002 9:00	7	11/10/2002 9:00	2	12/21/2002 9:00	2
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10/3/2002 9:00	2	11/13/2002 9:00	2	12/24/2002 9:00	2
10/4/2002 9:00	2	11/14/2002 9:00	2	12/25/2002 9:00	2
10/5/2002 9:00	2.2	11/15/2002 9:00	2	12/26/2002 9:00	2
10/6/2002 9:00	2	11/16/2002 9:00	2	12/27/2002 9:00	2
10/7/2002 9:00	2	11/17/2002 9:00	2	12/28/2002 9:00	2
10/8/2002 9:00	7	11/18/2002 9:00	2	12/29/2002 9:00	2
10/9/2002 9:00	7	11/19/2002 9:00	2	12/30/2002 9:00	2
10/10/2002 9:00	7	11/20/2002 9:00	2	12/31/2002 9:00	2
10/11/2002 9:00	2	11/21/2002 9:00	2		
10/12/2002 9:00	2	11/22/2002 9:00	2		
10/13/2002 9:00	2	11/23/2002 9:00	2		

2003					
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1/3/2003 9:00	2	2/13/2003 9:00	2	3/26/2003 9:00	2
1/4/2003 9:00	2	2/14/2003 9:00	2	3/27/2003 9:00	2
1/5/2003 9:00	2	2/15/2003 9:00	2	3/28/2003 9:00	2
1/6/2003 9:00	2	2/16/2003 9:00	2	3/29/2003 9:00	2
1/7/2003 9:00	2	2/17/2003 9:00	2	3/30/2003 9:00	2
1/8/2003 9:00	2	2/18/2003 9:00	2	3/31/2003 9:00	2
1/9/2003 9:00	2	2/19/2003 9:00	2	4/1/2003 9:00	2
1/10/2003 9:00	2	2/20/2003 9:00	2	4/2/2003 9:00	2
1/11/2003 9:00	2	2/21/2003 9:00	2	4/3/2003 9:00	2
1/12/2003 9:00	2	2/22/2003 9:00	2	4/4/2003 9:00	2
1/13/2003 9:00	2	2/23/2003 9:00	2	4/5/2003 9:00	2
1/14/2003 9:00	2	2/24/2003 9:00	2	4/6/2003 9:00	2
1/15/2003 9:00	2	2/25/2003 9:00	2	4/7/2003 9:00	2
1/16/2003 9:00	2	2/26/2003 9:00	2	4/8/2003 9:00	2
1/17/2003 9:00	2	2/27/2003 9:00	2	4/9/2003 9:00	2
1/18/2003 9:00	2	2/28/2003 9:00	2	4/10/2003 9:00	3.8
1/19/2003 9:00	2	3/1/2003 9:00	2	4/11/2003 9:00	2
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1/21/2003 9:00	2	3/3/2003 9:00	2	4/13/2003 9:00	2
1/22/2003 9:00	2	3/4/2003 9:00	2	4/14/2003 9:00	2
1/23/2003 9:00	2	3/5/2003 9:00	2	4/15/2003 9:00	2
1/24/2003 9:00	2	3/6/2003 9:00	2	4/16/2003 9:00	2
1/25/2003 9:00	2	3/7/2003 9:00	2	4/17/2003 9:00	2
1/26/2003 9:00	2	3/8/2003 9:00	2	4/18/2003 9:00	2
1/27/2003 9:00	2	3/9/2003 9:00	2	4/19/2003 9:00	2
1/28/2003 9:00	2	3/10/2003 9:00	2	4/20/2003 9:00	2
1/29/2003 9:00	2	3/11/2003 9:00	2	4/21/2003 9:00	2
1/30/2003 9:00	2	3/12/2003 9:00	2	4/22/2003 9:00	2
1/31/2003 9:00	2	3/13/2003 9:00	2	4/23/2003 9:00	2
2/1/2003 9:00	2	3/14/2003 9:00	2	4/24/2003 9:00	2
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2/3/2003 9:00	2	3/16/2003 9:00	2	4/26/2003 9:00	2.1
2/4/2003 9:00	2	3/17/2003 9:00	2	4/27/2003 9:00	2.1
2/5/2003 9:00	2	3/18/2003 9:00	2	4/28/2003 9:00	2.1
2/6/2003 9:00	2	3/19/2003 9:00	2	4/29/2003 9:00	2.1
2/7/2003 9:00	2	3/20/2003 9:00	2	4/30/2003 9:00	2.1
2/8/2003 9:00	2	3/21/2003 9:00	2	5/1/2003 9:00	2.1
2/9/2003 9:00	2	3/22/2003 9:00	2	5/2/2003 9:00	2.1
2/10/2003 9:00	2	3/23/2003 9:00	2	5/3/2003 9:00	2.1

Date and Time	ET Value	Date and Time	ET Value	Date and Time	ET Value
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5/6/2003 9:00	2	6/16/2003 9:00	2	7/27/2003 9:00	6.3
5/7/2003 9:00	2	6/17/2003 9:00	2	7/28/2003 9:00	2
5/8/2003 9:00	2	6/18/2003 9:00	2	7/29/2003 9:00	7
5/9/2003 9:00	4.2	6/19/2003 9:00	4.9	7/30/2003 9:00	2
5/10/2003 9:00	6.8	6/20/2003 9:00	2	7/31/2003 9:00	2
5/11/2003 9:00	2	6/21/2003 9:00	2	8/1/2003 9:00	2
5/12/2003 9:00	2.6	6/22/2003 9:00	7	8/2/2003 9:00	2
5/13/2003 9:00	7	6/23/2003 9:00	7	8/3/2003 9:00	2
5/14/2003 9:00	2	6/24/2003 9:00	7	8/4/2003 9:00	3.5
5/15/2003 9:00	7	6/25/2003 9:00	7	8/5/2003 9:00	2
5/16/2003 9:00	2	6/26/2003 9:00	7	8/6/2003 9:00	2
5/17/2003 9:00	2	6/27/2003 9:00	7	8/7/2003 9:00	2
5/18/2003 9:00	2	6/28/2003 9:00	2	8/8/2003 9:00	2
5/19/2003 9:00	2	6/29/2003 9:00	7	8/9/2003 9:00	6.2
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5/21/2003 9:00	3.5	7/1/2003 9:00	7	8/11/2003 9:00	2
5/22/2003 9:00	2	7/2/2003 9:00	7	8/12/2003 9:00	7
5/23/2003 9:00	2	7/3/2003 9:00	4.5	8/13/2003 9:00	7
5/24/2003 9:00	7	7/4/2003 9:00	2	8/14/2003 9:00	4.5
5/25/2003 9:00	2	7/5/2003 9:00	2	8/15/2003 9:00	7
5/26/2003 9:00	2	7/6/2003 9:00	2	8/16/2003 9:00	3.9
5/27/2003 9:00	2	7/7/2003 9:00	2	8/17/2003 9:00	4.5
5/28/2003 9:00	7	7/8/2003 9:00	2	8/18/2003 9:00	2
5/29/2003 9:00	2	7/9/2003 9:00	2	8/19/2003 9:00	2
5/30/2003 9:00	2	7/10/2003 9:00	7	8/20/2003 9:00	4
5/31/2003 9:00	2	7/11/2003 9:00	7	8/21/2003 9:00	5.9
6/1/2003 9:00	2	7/12/2003 9:00	7	8/22/2003 9:00	7
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6/3/2003 9:00	2	7/14/2003 9:00	2	8/24/2003 9:00	7
6/4/2003 9:00	2	7/15/2003 9:00	2	8/25/2003 9:00	7
6/5/2003 9:00	2	7/16/2003 9:00	2	8/26/2003 9:00	7
6/6/2003 9:00	2	7/17/2003 9:00	2	8/27/2003 9:00	7
6/7/2003 9:00	2	7/18/2003 9:00	2	8/28/2003 9:00	7
6/8/2003 9:00	2	7/19/2003 9:00	7	8/29/2003 9:00	2
6/9/2003 9:00	2	7/20/2003 9:00	7	8/30/2003 9:00	7
6/10/2003 9:00	7	7/21/2003 9:00	7	8/31/2003 9:00	7
6/11/2003 9:00	5.1	7/22/2003 9:00	2.4	9/1/2003 9:00	7
6/12/2003 9:00	2	7/23/2003 9:00	7	9/2/2003 9:00	2
6/13/2003 9:00	2	7/24/2003 9:00	2	9/3/2003 9:00	4.7

Date and Time	ET Value	Date and Time	ET Value	Date and Time	ET Value
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9/6/2003 9:00	2	10/17/2003 9:00	2	11/27/2003 9:00	2
9/7/2003 9:00	2	10/18/2003 9:00	7	11/28/2003 9:00	2
9/8/2003 9:00	2	10/19/2003 9:00	2.3	11/29/2003 9:00	2
9/9/2003 9:00	6.8	10/20/2003 9:00	7	11/30/2003 9:00	2
9/10/2003 9:00	2	10/21/2003 9:00	2	12/1/2003 9:00	2
9/11/2003 9:00	7	10/22/2003 9:00	2	12/2/2003 9:00	2
9/12/2003 9:00	7	10/23/2003 9:00	2	12/3/2003 9:00	2
9/13/2003 9:00	7	10/24/2003 9:00	2	12/4/2003 9:00	2
9/14/2003 9:00	5.2	10/25/2003 9:00	2	12/5/2003 9:00	2
9/15/2003 9:00	4.2	10/26/2003 9:00	2	12/6/2003 9:00	2
9/16/2003 9:00	2	10/27/2003 9:00	2	12/7/2003 9:00	2
9/17/2003 9:00	7	10/28/2003 9:00	2	12/8/2003 9:00	2
9/18/2003 9:00	4.4	10/29/2003 9:00	2	12/9/2003 9:00	2
9/19/2003 9:00	7	10/30/2003 9:00	2	12/10/2003 9:00	2
9/20/2003 9:00	2	10/31/2003 9:00	2	12/11/2003 9:00	2
9/21/2003 9:00	2	11/1/2003 9:00	2	12/12/2003 9:00	2
9/22/2003 9:00	7	11/2/2003 9:00	7	12/13/2003 9:00	2
9/23/2003 9:00	7	11/3/2003 9:00	5.1	12/14/2003 9:00	2
9/24/2003 9:00	7	11/4/2003 9:00	2	12/15/2003 9:00	2
9/25/2003 9:00	7	11/5/2003 9:00	2	12/16/2003 9:00	2
9/26/2003 9:00	7	11/6/2003 9:00	2	12/17/2003 9:00	2
9/27/2003 9:00	2	11/7/2003 9:00	2	12/18/2003 9:00	2
9/28/2003 9:00	4.5	11/8/2003 9:00	2	12/19/2003 9:00	2
9/29/2003 9:00	2	11/9/2003 9:00	2	12/20/2003 9:00	2
9/30/2003 9:00	2	11/10/2003 9:00	2	12/21/2003 9:00	2
10/1/2003 9:00	5.5	11/11/2003 9:00	2	12/22/2003 9:00	2
10/2/2003 9:00	2	11/12/2003 9:00	2	12/23/2003 9:00	2
10/3/2003 9:00	2	11/13/2003 9:00	2	12/24/2003 9:00	2
10/4/2003 9:00	2	11/14/2003 9:00	2	12/25/2003 9:00	2
10/5/2003 9:00	2	11/15/2003 9:00	2	12/26/2003 9:00	2
10/6/2003 9:00	2	11/16/2003 9:00	2	12/27/2003 9:00	2
10/7/2003 9:00	2	11/17/2003 9:00	2	12/28/2003 9:00	2
10/8/2003 9:00	2	11/18/2003 9:00	2	12/29/2003 9:00	2
10/9/2003 9:00	2.2	11/19/2003 9:00	2	12/30/2003 9:00	2
10/10/2003 9:00	2	11/20/2003 9:00	2	12/31/2003 9:00	2
10/11/2003 9:00	2	11/21/2003 9:00	2		
10/12/2003 9:00	2	11/22/2003 9:00	2		
10/13/2003 9:00	2	11/23/2003 9:00	2		
10/14/2003 9:00	2	11/24/2003 9:00	2		

2004					
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1/3/2004 9:00	2	2/13/2004 9:00	2	3/25/2004 9:00	2
1/4/2004 9:00	2	2/14/2004 9:00	2	3/26/2004 9:00	2
1/5/2004 9:00	2	2/15/2004 9:00	2	3/27/2004 9:00	2
1/6/2004 9:00	2	2/16/2004 9:00	2	3/28/2004 9:00	2
1/7/2004 9:00	2	2/17/2004 9:00	2	3/29/2004 9:00	2
1/8/2004 9:00	2	2/18/2004 9:00	2	3/30/2004 9:00	2
1/9/2004 9:00	2	2/19/2004 9:00	2	3/31/2004 9:00	2
1/10/2004 9:00	2	2/20/2004 9:00	2	4/1/2004 9:00	2
1/11/2004 9:00	2	2/21/2004 9:00	2	4/2/2004 9:00	2
1/12/2004 9:00	2	2/22/2004 9:00	2	4/3/2004 9:00	2
1/13/2004 9:00	2	2/23/2004 9:00	2	4/4/2004 9:00	2.1
1/14/2004 9:00	2	2/24/2004 9:00	2	4/5/2004 9:00	2.1
1/15/2004 9:00	2	2/25/2004 9:00	2	4/6/2004 9:00	2
1/16/2004 9:00	7	2/26/2004 9:00	2	4/7/2004 9:00	2
1/17/2004 9:00	2	2/27/2004 9:00	2	4/8/2004 9:00	2
1/18/2004 9:00	2	2/28/2004 9:00	2	4/9/2004 9:00	2
1/19/2004 9:00	2	2/29/2004 9:00	2	4/10/2004 9:00	2
1/20/2004 9:00	2	3/1/2004 9:00	2	4/11/2004 9:00	2
1/21/2004 9:00	2	3/2/2004 9:00	2	4/12/2004 9:00	4.1
1/22/2004 9:00	2	3/3/2004 9:00	2	4/13/2004 9:00	2
1/23/2004 9:00	2	3/4/2004 9:00	2	4/14/2004 9:00	2
1/24/2004 9:00	2	3/5/2004 9:00	2	4/15/2004 9:00	2
1/25/2004 9:00	2	3/6/2004 9:00	2	4/16/2004 9:00	2
1/26/2004 9:00	2	3/7/2004 9:00	2	4/17/2004 9:00	2
1/27/2004 9:00	2	3/8/2004 9:00	5.2	4/18/2004 9:00	2
1/28/2004 9:00	2	3/9/2004 9:00	2	4/19/2004 9:00	2
1/29/2004 9:00	2	3/10/2004 9:00	2	4/20/2004 9:00	2
1/30/2004 9:00	2	3/11/2004 9:00	2	4/21/2004 9:00	7
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2/2/2004 9:00	2	3/14/2004 9:00	2.6	4/24/2004 9:00	2
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2/4/2004 9:00	2	3/16/2004 9:00	2	4/26/2004 9:00	2
2/5/2004 9:00	5	3/17/2004 9:00	2	4/27/2004 9:00	2
2/6/2004 9:00	7	3/18/2004 9:00	2	4/28/2004 9:00	6.6
2/7/2004 9:00	7	3/19/2004 9:00	2	4/29/2004 9:00	2
2/8/2004 9:00	2	3/20/2004 9:00	2	4/30/2004 9:00	2
2/9/2004 9:00	2	3/21/2004 9:00	2	5/1/2004 9:00	2
2/10/2004 9:00	2	3/22/2004 9:00	2	5/2/2004 9:00	7

Date and Time	ET Value	Date and Time	ET Value	Date and Time	ET Value
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5/6/2004 9:00	2	6/16/2004 9:00	2	7/27/2004 9:00	2
5/7/2004 9:00	2	6/17/2004 9:00	2	7/28/2004 9:00	2
5/8/2004 9:00	2	6/18/2004 9:00	2	7/29/2004 9:00	7
5/9/2004 9:00	2	6/19/2004 9:00	4.9	7/30/2004 9:00	2
5/10/2004 9:00	2	6/20/2004 9:00	2	7/31/2004 9:00	2
5/11/2004 9:00	7	6/21/2004 9:00	2	8/1/2004 9:00	2
5/12/2004 9:00	2	6/22/2004 9:00	2	8/2/2004 9:00	2
5/13/2004 9:00	2	6/23/2004 9:00	7	8/3/2004 9:00	2
5/14/2004 9:00	2	6/24/2004 9:00	7	8/4/2004 9:00	2
5/15/2004 9:00	2.1	6/25/2004 9:00	2	8/5/2004 9:00	7
5/16/2004 9:00	2.1	6/26/2004 9:00	7	8/6/2004 9:00	2
5/17/2004 9:00	2.1	6/27/2004 9:00	2	8/7/2004 9:00	2
5/18/2004 9:00	2.1	6/28/2004 9:00	3	8/8/2004 9:00	2
5/19/2004 9:00	2.1	6/29/2004 9:00	2	8/9/2004 9:00	2
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5/21/2004 9:00	2	7/1/2004 9:00	7	8/11/2004 9:00	2
5/22/2004 9:00	7	7/2/2004 9:00	7	8/12/2004 9:00	7
5/23/2004 9:00	7	7/3/2004 9:00	2.1	8/13/2004 9:00	7
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5/25/2004 9:00	2.1	7/5/2004 9:00	2	8/15/2004 9:00	7
5/26/2004 9:00	2.1	7/6/2004 9:00	2	8/16/2004 9:00	7
5/27/2004 9:00	5.9	7/7/2004 9:00	6.5	8/17/2004 9:00	7
5/28/2004 9:00	2	7/8/2004 9:00	2	8/18/2004 9:00	2
5/29/2004 9:00	7	7/9/2004 9:00	2	8/19/2004 9:00	2
5/30/2004 9:00	2	7/10/2004 9:00	2	8/20/2004 9:00	2
5/31/2004 9:00	2	7/11/2004 9:00	2	8/21/2004 9:00	2
6/1/2004 9:00	2	7/12/2004 9:00	2	8/22/2004 9:00	3
6/2/2004 9:00	2	7/13/2004 9:00	2	8/23/2004 9:00	2
6/3/2004 9:00	2	7/14/2004 9:00	2.9	8/24/2004 9:00	2
6/4/2004 9:00	2.5	7/15/2004 9:00	2	8/25/2004 9:00	2
6/5/2004 9:00	2	7/16/2004 9:00	2	8/26/2004 9:00	2
6/6/2004 9:00	2	7/17/2004 9:00	2	8/27/2004 9:00	7
6/7/2004 9:00	2	7/18/2004 9:00	2	8/28/2004 9:00	7
6/8/2004 9:00	2.5	7/19/2004 9:00	2	8/29/2004 9:00	2
6/9/2004 9:00	2	7/20/2004 9:00	7	8/30/2004 9:00	2
6/10/2004 9:00	7	7/21/2004 9:00	7	8/31/2004 9:00	2
6/11/2004 9:00	2	7/22/2004 9:00	7	9/1/2004 9:00	2
6/12/2004 9:00	2	7/23/2004 9:00	2	9/2/2004 9:00	2

Date and Time	ET Value	Date and Time	ET Value	Date and Time	ET Value
9/3/2004 9:00	2	10/14/2004 9:00	2	11/24/2004 9:00	2
9/4/2004 9:00	3	10/15/2004 9:00	2	11/25/2004 9:00	2
9/5/2004 9:00	2	10/16/2004 9:00	2	11/26/2004 9:00	2
9/6/2004 9:00	2	10/17/2004 9:00	2	11/27/2004 9:00	2
9/7/2004 9:00	7	10/18/2004 9:00	2	11/28/2004 9:00	2
9/8/2004 9:00	2	10/19/2004 9:00	2	11/29/2004 9:00	2
9/9/2004 9:00	7	10/20/2004 9:00	2	11/30/2004 9:00	2
9/10/2004 9:00	2	10/21/2004 9:00	2	12/1/2004 9:00	2
9/11/2004 9:00	2	10/22/2004 9:00	2	12/2/2004 9:00	2
9/12/2004 9:00	4.2	10/23/2004 9:00	2	12/3/2004 9:00	2
9/13/2004 9:00	2	10/24/2004 9:00	2	12/4/2004 9:00	2
9/14/2004 9:00	2	10/25/2004 9:00	2	12/5/2004 9:00	2
9/15/2004 9:00	2	10/26/2004 9:00	2	12/6/2004 9:00	2
9/16/2004 9:00	2	10/27/2004 9:00	2	12/7/2004 9:00	2
9/17/2004 9:00	2	10/28/2004 9:00	2	12/8/2004 9:00	2
9/18/2004 9:00	7	10/29/2004 9:00	2	12/9/2004 9:00	2
9/19/2004 9:00	2	10/30/2004 9:00	2	12/10/2004 9:00	2
9/20/2004 9:00	2	10/31/2004 9:00	2	12/11/2004 9:00	2
9/21/2004 9:00	2	11/1/2004 9:00	2	12/12/2004 9:00	2
9/22/2004 9:00	7	11/2/2004 9:00	2	12/13/2004 9:00	2
9/23/2004 9:00	7	11/3/2004 9:00	2	12/14/2004 9:00	2
9/24/2004 9:00	5	11/4/2004 9:00	2	12/15/2004 9:00	2
9/25/2004 9:00	7	11/5/2004 9:00	2	12/16/2004 9:00	2
9/26/2004 9:00	2	11/6/2004 9:00	2	12/17/2004 9:00	2
9/27/2004 9:00	2	11/7/2004 9:00	2	12/18/2004 9:00	2
9/28/2004 9:00	5.3	11/8/2004 9:00	2	12/19/2004 9:00	2
9/29/2004 9:00	2	11/9/2004 9:00	2	12/20/2004 9:00	2
9/30/2004 9:00	7	11/10/2004 9:00	2	12/21/2004 9:00	2
10/1/2004 9:00	2	11/11/2004 9:00	2	12/22/2004 9:00	2
10/2/2004 9:00	2	11/12/2004 9:00	2	12/23/2004 9:00	2
10/3/2004 9:00	2	11/13/2004 9:00	2	12/24/2004 9:00	2
10/4/2004 9:00	2	11/14/2004 9:00	2.3	12/25/2004 9:00	2
10/5/2004 9:00	2	11/15/2004 9:00	2	12/26/2004 9:00	2
10/6/2004 9:00	2	11/16/2004 9:00	2	12/27/2004 9:00	2
10/7/2004 9:00	2	11/17/2004 9:00	2	12/28/2004 9:00	2
10/8/2004 9:00	2	11/18/2004 9:00	2	12/29/2004 9:00	2
10/9/2004 9:00	7	11/19/2004 9:00	2	12/30/2004 9:00	2
10/10/2004 9:00	2	11/20/2004 9:00	2	12/31/2004 9:00	2
10/11/2004 9:00	7	11/21/2004 9:00	2		
10/12/2004 9:00	2	11/22/2004 9:00	2		
10/13/2004 9:00	2	11/23/2004 9:00	2		

2005					
Date and Time	ET Value	Date and Time	ET Value	Date and Time	ET Value
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1/2/2005 9:00	2	2/12/2005 9:00	7	3/25/2005 9:00	2
1/3/2005 9:00	2	2/13/2005 9:00	2	3/26/2005 9:00	2
1/4/2005 9:00	2	2/14/2005 9:00	2	3/27/2005 9:00	2
1/5/2005 9:00	2	2/15/2005 9:00	2	3/28/2005 9:00	2
1/6/2005 9:00	2	2/16/2005 9:00	2	3/29/2005 9:00	2
1/7/2005 9:00	2	2/17/2005 9:00	2	3/30/2005 9:00	2
1/8/2005 9:00	2	2/18/2005 9:00	2	3/31/2005 9:00	7
1/9/2005 9:00	2	2/19/2005 9:00	2	4/1/2005 9:00	2
1/10/2005 9:00	2	2/20/2005 9:00	7	4/2/2005 9:00	2
1/11/2005 9:00	2	2/21/2005 9:00	2	4/3/2005 9:00	2
1/12/2005 9:00	2	2/22/2005 9:00	2	4/4/2005 9:00	4
1/13/2005 9:00	2	2/23/2005 9:00	2	4/5/2005 9:00	2
1/14/2005 9:00	2	2/24/2005 9:00	2	4/6/2005 9:00	2
1/15/2005 9:00	2	2/25/2005 9:00	2	4/7/2005 9:00	2
1/16/2005 9:00	2	2/26/2005 9:00	2	4/8/2005 9:00	2
1/17/2005 9:00	2	2/27/2005 9:00	2	4/9/2005 9:00	2
1/18/2005 9:00	2	2/28/2005 9:00	2	4/10/2005 9:00	2
1/19/2005 9:00	2	3/1/2005 9:00	2	4/11/2005 9:00	2.5
1/20/2005 9:00	2	3/2/2005 9:00	2	4/12/2005 9:00	2.5
1/21/2005 9:00	2	3/3/2005 9:00	2	4/13/2005 9:00	2.5
1/22/2005 9:00	2	3/4/2005 9:00	2	4/14/2005 9:00	2.5
1/23/2005 9:00	2	3/5/2005 9:00	2	4/15/2005 9:00	7
1/24/2005 9:00	2	3/6/2005 9:00	2	4/16/2005 9:00	2.3
1/25/2005 9:00	2	3/7/2005 9:00	2	4/17/2005 9:00	2
1/26/2005 9:00	2	3/8/2005 9:00	2	4/18/2005 9:00	2
1/27/2005 9:00	2	3/9/2005 9:00	2	4/19/2005 9:00	2
1/28/2005 9:00	2	3/10/2005 9:00	2	4/20/2005 9:00	2
1/29/2005 9:00	2	3/11/2005 9:00	2	4/21/2005 9:00	2
1/30/2005 9:00	2	3/12/2005 9:00	7	4/22/2005 9:00	2
1/31/2005 9:00	2	3/13/2005 9:00	7	4/23/2005 9:00	2
2/1/2005 9:00	2	3/14/2005 9:00	2	4/24/2005 9:00	2
2/2/2005 9:00	2.5	3/15/2005 9:00	2	4/25/2005 9:00	2
2/3/2005 9:00	2	3/16/2005 9:00	2	4/26/2005 9:00	2
2/4/2005 9:00	2	3/17/2005 9:00	2	4/27/2005 9:00	2
2/5/2005 9:00	2	3/18/2005 9:00	2	4/28/2005 9:00	2
2/6/2005 9:00	7	3/19/2005 9:00	2	4/29/2005 9:00	2
2/7/2005 9:00	2	3/20/2005 9:00	2	4/30/2005 9:00	2
2/8/2005 9:00	2	3/21/2005 9:00	2	5/1/2005 9:00	2
2/9/2005 9:00	2	3/22/2005 9:00	2	5/2/2005 9:00	2

Date and Time	ET Value	Date and Time	ET Value	Date and Time	ET Value
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5/5/2005 9:00	2	6/15/2005 9:00	2	7/26/2005 9:00	7
5/6/2005 9:00	2.5	6/16/2005 9:00	2	7/27/2005 9:00	2
5/7/2005 9:00	2.5	6/17/2005 9:00	2.5	7/28/2005 9:00	2
5/8/2005 9:00	2.5	6/18/2005 9:00	2	7/29/2005 9:00	7
5/9/2005 9:00	2.5	6/19/2005 9:00	2	7/30/2005 9:00	7
5/10/2005 9:00	2.5	6/20/2005 9:00	2	7/31/2005 9:00	6
5/11/2005 9:00	2.5	6/21/2005 9:00	2	8/1/2005 9:00	2
5/12/2005 9:00	7	6/22/2005 9:00	7	8/2/2005 9:00	7
5/13/2005 9:00	2	6/23/2005 9:00	7	8/3/2005 9:00	2
5/14/2005 9:00	2	6/24/2005 9:00	7	8/4/2005 9:00	2
5/15/2005 9:00	7	6/25/2005 9:00	2	8/5/2005 9:00	2
5/16/2005 9:00	7	6/26/2005 9:00	2	8/6/2005 9:00	2
5/17/2005 9:00	2	6/27/2005 9:00	7	8/7/2005 9:00	2
5/18/2005 9:00	2	6/28/2005 9:00	7	8/8/2005 9:00	2
5/19/2005 9:00	6.2	6/29/2005 9:00	7	8/9/2005 9:00	2
5/20/2005 9:00	2	6/30/2005 9:00	6.9	8/10/2005 9:00	2
5/21/2005 9:00	7	7/1/2005 9:00	2	8/11/2005 9:00	2
5/22/2005 9:00	2	7/2/2005 9:00	7	8/12/2005 9:00	2
5/23/2005 9:00	2	7/3/2005 9:00	6.9	8/13/2005 9:00	7
5/24/2005 9:00	2	7/4/2005 9:00	2	8/14/2005 9:00	2
5/25/2005 9:00	2.5	7/5/2005 9:00	2	8/15/2005 9:00	6.7
5/26/2005 9:00	2.5	7/6/2005 9:00	2	8/16/2005 9:00	2
5/27/2005 9:00	2.5	7/7/2005 9:00	2	8/17/2005 9:00	2
5/28/2005 9:00	2.5	7/8/2005 9:00	2	8/18/2005 9:00	2
5/29/2005 9:00	2.5	7/9/2005 9:00	2	8/19/2005 9:00	2
5/30/2005 9:00	2.5	7/10/2005 9:00	2	8/20/2005 9:00	2
5/31/2005 9:00	2	7/11/2005 9:00	2	8/21/2005 9:00	2
6/1/2005 9:00	2.5	7/12/2005 9:00	2	8/22/2005 9:00	2
6/2/2005 9:00	2.5	7/13/2005 9:00	7	8/23/2005 9:00	7
6/3/2005 9:00	2.5	7/14/2005 9:00	7	8/24/2005 9:00	2
6/4/2005 9:00	2	7/15/2005 9:00	7	8/25/2005 9:00	2
6/5/2005 9:00	5.9	7/16/2005 9:00	2	8/26/2005 9:00	2
6/6/2005 9:00	2	7/17/2005 9:00	2	8/27/2005 9:00	2
6/7/2005 9:00	2	7/18/2005 9:00	2	8/28/2005 9:00	2
6/8/2005 9:00	2	7/19/2005 9:00	2	8/29/2005 9:00	2
6/9/2005 9:00	7	7/20/2005 9:00	2	8/30/2005 9:00	7
6/10/2005 9:00	7	7/21/2005 9:00	2	8/31/2005 9:00	2
6/11/2005 9:00	2	7/22/2005 9:00	7	9/1/2005 9:00	2
6/12/2005 9:00	7	7/23/2005 9:00	2	9/2/2005 9:00	2

Date and Time	ET Value	Date and Time	ET Value	Date and Time	ET Value
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9/5/2005 9:00	2	10/16/2005 9:00	2	11/26/2005 9:00	2
9/6/2005 9:00	3.2	10/17/2005 9:00	2	11/27/2005 9:00	2
9/7/2005 9:00	3.9	10/18/2005 9:00	2	11/28/2005 9:00	2
9/8/2005 9:00	7	10/19/2005 9:00	2	11/29/2005 9:00	2
9/9/2005 9:00	3.5	10/20/2005 9:00	2	11/30/2005 9:00	2
9/10/2005 9:00	4.2	10/21/2005 9:00	2	12/1/2005 9:00	2
9/11/2005 9:00	2	10/22/2005 9:00	2	12/2/2005 9:00	2
9/12/2005 9:00	7	10/23/2005 9:00	2	12/3/2005 9:00	2
9/13/2005 9:00	2	10/24/2005 9:00	2	12/4/2005 9:00	2
9/14/2005 9:00	2	10/25/2005 9:00	3	12/5/2005 9:00	2
9/15/2005 9:00	2	10/26/2005 9:00	4.2	12/6/2005 9:00	2
9/16/2005 9:00	2	10/27/2005 9:00	7	12/7/2005 9:00	2
9/17/2005 9:00	2	10/28/2005 9:00	2	12/8/2005 9:00	2
9/18/2005 9:00	2	10/29/2005 9:00	2	12/9/2005 9:00	2
9/19/2005 9:00	2	10/30/2005 9:00	2	12/10/2005 9:00	2
9/20/2005 9:00	2	10/31/2005 9:00	2	12/11/2005 9:00	2
9/21/2005 9:00	2	11/1/2005 9:00	2	12/12/2005 9:00	2
9/22/2005 9:00	7	11/2/2005 9:00	2	12/13/2005 9:00	2
9/23/2005 9:00	2	11/3/2005 9:00	2	12/14/2005 9:00	2
9/24/2005 9:00	2	11/4/2005 9:00	2	12/15/2005 9:00	2
9/25/2005 9:00	7	11/5/2005 9:00	2	12/16/2005 9:00	2
9/26/2005 9:00	7	11/6/2005 9:00	2	12/17/2005 9:00	2
9/27/2005 9:00	2	11/7/2005 9:00	2	12/18/2005 9:00	2
9/28/2005 9:00	2	11/8/2005 9:00	2	12/19/2005 9:00	2
9/29/2005 9:00	2	11/9/2005 9:00	2	12/20/2005 9:00	2
9/30/2005 9:00	7	11/10/2005 9:00	2	12/21/2005 9:00	2
10/1/2005 9:00	2	11/11/2005 9:00	2	12/22/2005 9:00	2
10/2/2005 9:00	7	11/12/2005 9:00	2	12/23/2005 9:00	2
10/3/2005 9:00	2	11/13/2005 9:00	2	12/24/2005 9:00	2
10/4/2005 9:00	2	11/14/2005 9:00	2	12/25/2005 9:00	2
10/5/2005 9:00	2.2	11/15/2005 9:00	2	12/26/2005 9:00	2
10/6/2005 9:00	2	11/16/2005 9:00	2	12/27/2005 9:00	2
10/7/2005 9:00	2	11/17/2005 9:00	2	12/28/2005 9:00	2
10/8/2005 9:00	7	11/18/2005 9:00	2	12/29/2005 9:00	2
10/9/2005 9:00	7	11/19/2005 9:00	2	12/30/2005 9:00	2
10/10/2005 9:00	7	11/20/2005 9:00	2	12/31/2005 9:00	2
10/11/2005 9:00	2	11/21/2005 9:00	2		
10/12/2005 9:00	2	11/22/2005 9:00	2		
10/13/2005 9:00	2	11/23/2005 9:00	2		

2006					
Date and Time	ET Value	Date and Time	ET Value	Date and Time	ET Value
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1/2/2006 9:00	2	2/12/2006 9:00	2	3/25/2006 9:00	2
1/3/2006 9:00	2	2/13/2006 9:00	2	3/26/2006 9:00	2
1/4/2006 9:00	2	2/14/2006 9:00	2	3/27/2006 9:00	2
1/5/2006 9:00	2	2/15/2006 9:00	2	3/28/2006 9:00	2
1/6/2006 9:00	2	2/16/2006 9:00	2	3/29/2006 9:00	2
1/7/2006 9:00	2	2/17/2006 9:00	2	3/30/2006 9:00	2
1/8/2006 9:00	2	2/18/2006 9:00	2	3/31/2006 9:00	2
1/9/2006 9:00	2	2/19/2006 9:00	2	4/1/2006 9:00	2
1/10/2006 9:00	2	2/20/2006 9:00	2	4/2/2006 9:00	7
1/11/2006 9:00	2	2/21/2006 9:00	2	4/3/2006 9:00	7
1/12/2006 9:00	2	2/22/2006 9:00	2	4/4/2006 9:00	2
1/13/2006 9:00	2	2/23/2006 9:00	2	4/5/2006 9:00	2
1/14/2006 9:00	2	2/24/2006 9:00	2	4/6/2006 9:00	2
1/15/2006 9:00	2	2/25/2006 9:00	2	4/7/2006 9:00	2
1/16/2006 9:00	2	2/26/2006 9:00	2	4/8/2006 9:00	2
1/17/2006 9:00	2	2/27/2006 9:00	2	4/9/2006 9:00	7
1/18/2006 9:00	2	2/28/2006 9:00	2	4/10/2006 9:00	2
1/19/2006 9:00	7	3/1/2006 9:00	2	4/11/2006 9:00	7
1/20/2006 9:00	2	3/2/2006 9:00	2	4/12/2006 9:00	2
1/21/2006 9:00	2	3/3/2006 9:00	2	4/13/2006 9:00	2
1/22/2006 9:00	2	3/4/2006 9:00	2	4/14/2006 9:00	2
1/23/2006 9:00	3.5	3/5/2006 9:00	2	4/15/2006 9:00	2
1/24/2006 9:00	2	3/6/2006 9:00	2	4/16/2006 9:00	2
1/25/2006 9:00	2	3/7/2006 9:00	2	4/17/2006 9:00	2
1/26/2006 9:00	2	3/8/2006 9:00	2	4/18/2006 9:00	2
1/27/2006 9:00	2	3/9/2006 9:00	2	4/19/2006 9:00	2
1/28/2006 9:00	2	3/10/2006 9:00	2	4/20/2006 9:00	2
1/29/2006 9:00	2	3/11/2006 9:00	2	4/21/2006 9:00	2
1/30/2006 9:00	2	3/12/2006 9:00	2	4/22/2006 9:00	2
1/31/2006 9:00	2	3/13/2006 9:00	2	4/23/2006 9:00	2
2/1/2006 9:00	2	3/14/2006 9:00	2	4/24/2006 9:00	2
2/2/2006 9:00	2	3/15/2006 9:00	2	4/25/2006 9:00	2
2/3/2006 9:00	2	3/16/2006 9:00	2	4/26/2006 9:00	2
2/4/2006 9:00	2	3/17/2006 9:00	2	4/27/2006 9:00	7
2/5/2006 9:00	2	3/18/2006 9:00	2	4/28/2006 9:00	2
2/6/2006 9:00	2	3/19/2006 9:00	2	4/29/2006 9:00	2
2/7/2006 9:00	2	3/20/2006 9:00	2	4/30/2006 9:00	2
2/8/2006 9:00	2	3/21/2006 9:00	2	5/1/2006 9:00	2.5
2/9/2006 9:00	2	3/22/2006 9:00	2	5/2/2006 9:00	3
2/10/2006 9:00	2	3/23/2006 9:00	2	5/3/2006 9:00	2.5

Date and Time	ET Value	Date and Time	ET Value	Date and Time	ET Value
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5/6/2006 9:00	2	6/16/2006 9:00	2	7/27/2006 9:00	2
5/7/2006 9:00	4.7	6/17/2006 9:00	2	7/28/2006 9:00	2
5/8/2006 9:00	2.5	6/18/2006 9:00	2	7/29/2006 9:00	7
5/9/2006 9:00	2.5	6/19/2006 9:00	4.9	7/30/2006 9:00	2
5/10/2006 9:00	3	6/20/2006 9:00	2	7/31/2006 9:00	2
5/11/2006 9:00	2.5	6/21/2006 9:00	2	8/1/2006 9:00	2
5/12/2006 9:00	4.2	6/22/2006 9:00	2	8/2/2006 9:00	2
5/13/2006 9:00	2.5	6/23/2006 9:00	7	8/3/2006 9:00	2
5/14/2006 9:00	2.5	6/24/2006 9:00	7	8/4/2006 9:00	2
5/15/2006 9:00	7	6/25/2006 9:00	2	8/5/2006 9:00	7
5/16/2006 9:00	3.2	6/26/2006 9:00	7	8/6/2006 9:00	2
5/17/2006 9:00	2.5	6/27/2006 9:00	2	8/7/2006 9:00	2
5/18/2006 9:00	2.5	6/28/2006 9:00	3	8/8/2006 9:00	2
5/19/2006 9:00	2.5	6/29/2006 9:00	2	8/9/2006 9:00	2
5/20/2006 9:00	2.5	6/30/2006 9:00	7	8/10/2006 9:00	7
5/21/2006 9:00	2.5	7/1/2006 9:00	7	8/11/2006 9:00	2
5/22/2006 9:00	3	7/2/2006 9:00	7	8/12/2006 9:00	7
5/23/2006 9:00	2.5	7/3/2006 9:00	2.1	8/13/2006 9:00	7
5/24/2006 9:00	3	7/4/2006 9:00	7	8/14/2006 9:00	7
5/25/2006 9:00	3.3	7/5/2006 9:00	2	8/15/2006 9:00	7
5/26/2006 9:00	3	7/6/2006 9:00	2	8/16/2006 9:00	7
5/27/2006 9:00	2	7/7/2006 9:00	6.5	8/17/2006 9:00	7
5/28/2006 9:00	2	7/8/2006 9:00	2	8/18/2006 9:00	2
5/29/2006 9:00	5.1	7/9/2006 9:00	2	8/19/2006 9:00	2
5/30/2006 9:00	2	7/10/2006 9:00	2	8/20/2006 9:00	2
5/31/2006 9:00	2	7/11/2006 9:00	2	8/21/2006 9:00	2
6/1/2006 9:00	2	7/12/2006 9:00	2	8/22/2006 9:00	3
6/2/2006 9:00	2	7/13/2006 9:00	2	8/23/2006 9:00	2
6/3/2006 9:00	2	7/14/2006 9:00	2.9	8/24/2006 9:00	2
6/4/2006 9:00	2.5	7/15/2006 9:00	2	8/25/2006 9:00	2
6/5/2006 9:00	2	7/16/2006 9:00	2	8/26/2006 9:00	2
6/6/2006 9:00	2	7/17/2006 9:00	2	8/27/2006 9:00	7
6/7/2006 9:00	2	7/18/2006 9:00	2	8/28/2006 9:00	7
6/8/2006 9:00	2.5	7/19/2006 9:00	2	8/29/2006 9:00	2
6/9/2006 9:00	2	7/20/2006 9:00	7	8/30/2006 9:00	2
6/10/2006 9:00	7	7/21/2006 9:00	7	8/31/2006 9:00	2
6/11/2006 9:00	2	7/22/2006 9:00	7	9/1/2006 9:00	2
6/12/2006 9:00	2	7/23/2006 9:00	2	9/2/2006 9:00	2
6/13/2006 9:00	4	7/24/2006 9:00	2	9/3/2006 9:00	2

Date and Time	ET Value	Date and Time	ET Value	Date and Time	ET Value
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9/5/2006 9:00	2	10/16/2006 9:00	2	11/26/2006 9:00	2
9/6/2006 9:00	2	10/17/2006 9:00	2	11/27/2006 9:00	2
9/7/2006 9:00	7	10/18/2006 9:00	2	11/28/2006 9:00	2
9/8/2006 9:00	2	10/19/2006 9:00	2	11/29/2006 9:00	2
9/9/2006 9:00	7	10/20/2006 9:00	2	11/30/2006 9:00	2
9/10/2006 9:00	2	10/21/2006 9:00	2	12/1/2006 9:00	2
9/11/2006 9:00	2	10/22/2006 9:00	2	12/2/2006 9:00	2
9/12/2006 9:00	4.2	10/23/2006 9:00	2	12/3/2006 9:00	2
9/13/2006 9:00	2	10/24/2006 9:00	2	12/4/2006 9:00	2
9/14/2006 9:00	2	10/25/2006 9:00	2	12/5/2006 9:00	2
9/15/2006 9:00	2	10/26/2006 9:00	2	12/6/2006 9:00	2
9/16/2006 9:00	2	10/27/2006 9:00	2	12/7/2006 9:00	2
9/17/2006 9:00	2	10/28/2006 9:00	2	12/8/2006 9:00	2
9/18/2006 9:00	7	10/29/2006 9:00	2	12/9/2006 9:00	2
9/19/2006 9:00	2	10/30/2006 9:00	2	12/10/2006 9:00	2
9/20/2006 9:00	2	10/31/2006 9:00	2	12/11/2006 9:00	2
9/21/2006 9:00	2	11/1/2006 9:00	2	12/12/2006 9:00	2
9/22/2006 9:00	7	11/2/2006 9:00	2	12/13/2006 9:00	2
9/23/2006 9:00	7	11/3/2006 9:00	2	12/14/2006 9:00	2
9/24/2006 9:00	5	11/4/2006 9:00	2	12/15/2006 9:00	2
9/25/2006 9:00	7	11/5/2006 9:00	2	12/16/2006 9:00	2
9/26/2006 9:00	2	11/6/2006 9:00	2	12/17/2006 9:00	2
9/27/2006 9:00	2	11/7/2006 9:00	2	12/18/2006 9:00	2
9/28/2006 9:00	5.3	11/8/2006 9:00	2	12/19/2006 9:00	2
9/29/2006 9:00	2	11/9/2006 9:00	2	12/20/2006 9:00	2
9/30/2006 9:00	7	11/10/2006 9:00	2	12/21/2006 9:00	2
10/1/2006 9:00	2	11/11/2006 9:00	2	12/22/2006 9:00	2
10/2/2006 9:00	2	11/12/2006 9:00	2	12/23/2006 9:00	2
10/3/2006 9:00	2	11/13/2006 9:00	2	12/24/2006 9:00	2
10/4/2006 9:00	2	11/14/2006 9:00	2.3	12/25/2006 9:00	2
10/5/2006 9:00	2	11/15/2006 9:00	2	12/26/2006 9:00	2
10/6/2006 9:00	2	11/16/2006 9:00	2	12/27/2006 9:00	2
10/7/2006 9:00	2	11/17/2006 9:00	2	12/28/2006 9:00	2
10/8/2006 9:00	2	11/18/2006 9:00	2	12/29/2006 9:00	2
10/9/2006 9:00	7	11/19/2006 9:00	2	12/30/2006 9:00	2
10/10/2006 9:00	2	11/20/2006 9:00	2	12/31/2006 9:00	2
10/11/2006 9:00	7	11/21/2006 9:00	2		
10/12/2006 9:00	2	11/22/2006 9:00	2		
10/13/2006 9:00	2	11/23/2006 9:00	2		
10/14/2006 9:00	2	11/24/2006 9:00	2		

2007					
Date and Time	ET Value	Date and Time	ET Value	Date and Time	ET Value
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1/2/2007 9:00	2	2/12/2007 9:00	7	3/25/2007 9:00	2
1/3/2007 9:00	2	2/13/2007 9:00	2	3/26/2007 9:00	2
1/4/2007 9:00	2	2/14/2007 9:00	2	3/27/2007 9:00	2
1/5/2007 9:00	2	2/15/2007 9:00	2	3/28/2007 9:00	2
1/6/2007 9:00	2	2/16/2007 9:00	2	3/29/2007 9:00	2
1/7/2007 9:00	2	2/17/2007 9:00	2	3/30/2007 9:00	2
1/8/2007 9:00	2	2/18/2007 9:00	2	3/31/2007 9:00	7
1/9/2007 9:00	2	2/19/2007 9:00	2	4/1/2007 9:00	2
1/10/2007 9:00	2	2/20/2007 9:00	7	4/2/2007 9:00	2
1/11/2007 9:00	2	2/21/2007 9:00	2	4/3/2007 9:00	2
1/12/2007 9:00	2	2/22/2007 9:00	2	4/4/2007 9:00	4
1/13/2007 9:00	2	2/23/2007 9:00	2	4/5/2007 9:00	2
1/14/2007 9:00	2	2/24/2007 9:00	2	4/6/2007 9:00	2
1/15/2007 9:00	2	2/25/2007 9:00	2	4/7/2007 9:00	2
1/16/2007 9:00	2	2/26/2007 9:00	2	4/8/2007 9:00	2
1/17/2007 9:00	2	2/27/2007 9:00	2	4/9/2007 9:00	2
1/18/2007 9:00	2	2/28/2007 9:00	2	4/10/2007 9:00	2
1/19/2007 9:00	2	3/1/2007 9:00	2	4/11/2007 9:00	2.5
1/20/2007 9:00	2	3/2/2007 9:00	2	4/12/2007 9:00	2.5
1/21/2007 9:00	2	3/3/2007 9:00	2	4/13/2007 9:00	2.5
1/22/2007 9:00	2	3/4/2007 9:00	2	4/14/2007 9:00	2.5
1/23/2007 9:00	2	3/5/2007 9:00	2	4/15/2007 9:00	7
1/24/2007 9:00	2	3/6/2007 9:00	2	4/16/2007 9:00	2.3
1/25/2007 9:00	2	3/7/2007 9:00	2	4/17/2007 9:00	2
1/26/2007 9:00	2	3/8/2007 9:00	2	4/18/2007 9:00	2
1/27/2007 9:00	2	3/9/2007 9:00	2	4/19/2007 9:00	2
1/28/2007 9:00	2	3/10/2007 9:00	2	4/20/2007 9:00	2
1/29/2007 9:00	2	3/11/2007 9:00	2	4/21/2007 9:00	2
1/30/2007 9:00	2	3/12/2007 9:00	7	4/22/2007 9:00	2
1/31/2007 9:00	2	3/13/2007 9:00	7	4/23/2007 9:00	2
2/1/2007 9:00	2	3/14/2007 9:00	2	4/24/2007 9:00	2
2/2/2007 9:00	2.5	3/15/2007 9:00	2	4/25/2007 9:00	2
2/3/2007 9:00	2	3/16/2007 9:00	2	4/26/2007 9:00	2
2/4/2007 9:00	2	3/17/2007 9:00	2	4/27/2007 9:00	2
2/5/2007 9:00	2	3/18/2007 9:00	2	4/28/2007 9:00	2
2/6/2007 9:00	7	3/19/2007 9:00	2	4/29/2007 9:00	2
2/7/2007 9:00	2	3/20/2007 9:00	2	4/30/2007 9:00	2
2/8/2007 9:00	2	3/21/2007 9:00	2	5/1/2007 9:00	2
2/9/2007 9:00	2	3/22/2007 9:00	2	5/2/2007 9:00	2
2/10/2007 9:00	2	3/23/2007 9:00	2	5/3/2007 9:00	2

Date and Time	ET Value	Date and Time	ET Value	Date and Time	ET Value
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5/5/2007 9:00	2	6/15/2007 9:00	2	7/26/2007 9:00	7
5/6/2007 9:00	2.5	6/16/2007 9:00	2	7/27/2007 9:00	2
5/7/2007 9:00	2.5	6/17/2007 9:00	2.5	7/28/2007 9:00	2
5/8/2007 9:00	2.5	6/18/2007 9:00	2	7/29/2007 9:00	7
5/9/2007 9:00	2.5	6/19/2007 9:00	2	7/30/2007 9:00	7
5/10/2007 9:00	2.5	6/20/2007 9:00	2	7/31/2007 9:00	6
5/11/2007 9:00	2.5	6/21/2007 9:00	2	8/1/2007 9:00	2
5/12/2007 9:00	7	6/22/2007 9:00	7	8/2/2007 9:00	7
5/13/2007 9:00	2	6/23/2007 9:00	7	8/3/2007 9:00	2
5/14/2007 9:00	2	6/24/2007 9:00	7	8/4/2007 9:00	2
5/15/2007 9:00	7	6/25/2007 9:00	2	8/5/2007 9:00	2
5/16/2007 9:00	7	6/26/2007 9:00	2	8/6/2007 9:00	2
5/17/2007 9:00	2	6/27/2007 9:00	7	8/7/2007 9:00	2
5/18/2007 9:00	2	6/28/2007 9:00	7	8/8/2007 9:00	2
5/19/2007 9:00	6.2	6/29/2007 9:00	7	8/9/2007 9:00	2
5/20/2007 9:00	2	6/30/2007 9:00	6.9	8/10/2007 9:00	2
5/21/2007 9:00	7	7/1/2007 9:00	2	8/11/2007 9:00	2
5/22/2007 9:00	2	7/2/2007 9:00	7	8/12/2007 9:00	2
5/23/2007 9:00	2	7/3/2007 9:00	6.9	8/13/2007 9:00	7
5/24/2007 9:00	2	7/4/2007 9:00	2	8/14/2007 9:00	2
5/25/2007 9:00	2.5	7/5/2007 9:00	2	8/15/2007 9:00	6.7
5/26/2007 9:00	2.5	7/6/2007 9:00	2	8/16/2007 9:00	2
5/27/2007 9:00	2.5	7/7/2007 9:00	2	8/17/2007 9:00	2
5/28/2007 9:00	2.5	7/8/2007 9:00	2	8/18/2007 9:00	2
5/29/2007 9:00	2.5	7/9/2007 9:00	2	8/19/2007 9:00	2
5/30/2007 9:00	2.5	7/10/2007 9:00	2	8/20/2007 9:00	2
5/31/2007 9:00	2	7/11/2007 9:00	2	8/21/2007 9:00	2
6/1/2007 9:00	2.5	7/12/2007 9:00	2	8/22/2007 9:00	2
6/2/2007 9:00	2.5	7/13/2007 9:00	7	8/23/2007 9:00	7
6/3/2007 9:00	2.5	7/14/2007 9:00	7	8/24/2007 9:00	2
6/4/2007 9:00	2	7/15/2007 9:00	7	8/25/2007 9:00	2
6/5/2007 9:00	5.9	7/16/2007 9:00	2	8/26/2007 9:00	2
6/6/2007 9:00	2	7/17/2007 9:00	2	8/27/2007 9:00	2
6/7/2007 9:00	2	7/18/2007 9:00	2	8/28/2007 9:00	2
6/8/2007 9:00	2	7/19/2007 9:00	2	8/29/2007 9:00	2
6/9/2007 9:00	7	7/20/2007 9:00	2	8/30/2007 9:00	7
6/10/2007 9:00	7	7/21/2007 9:00	2	8/31/2007 9:00	2
6/11/2007 9:00	2	7/22/2007 9:00	7	9/1/2007 9:00	2
6/12/2007 9:00	7	7/23/2007 9:00	2	9/2/2007 9:00	2
6/13/2007 9:00	2	7/24/2007 9:00	2	9/3/2007 9:00	2

Date and Time	ET Value	Date and Time	ET Value	Date and Time	ET Value
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9/5/2007 9:00	2	10/16/2007 9:00	2	11/26/2007 9:00	2
9/6/2007 9:00	3.2	10/17/2007 9:00	2	11/27/2007 9:00	2
9/7/2007 9:00	3.9	10/18/2007 9:00	2	11/28/2007 9:00	2
9/8/2007 9:00	7	10/19/2007 9:00	2	11/29/2007 9:00	2
9/9/2007 9:00	3.5	10/20/2007 9:00	2	11/30/2007 9:00	2
9/10/2007 9:00	4.2	10/21/2007 9:00	2	12/1/2007 9:00	2
9/11/2007 9:00	2	10/22/2007 9:00	2	12/2/2007 9:00	2
9/12/2007 9:00	7	10/23/2007 9:00	2	12/3/2007 9:00	2
9/13/2007 9:00	2	10/24/2007 9:00	2	12/4/2007 9:00	2
9/14/2007 9:00	2	10/25/2007 9:00	3	12/5/2007 9:00	2
9/15/2007 9:00	2	10/26/2007 9:00	4.2	12/6/2007 9:00	2
9/16/2007 9:00	2	10/27/2007 9:00	7	12/7/2007 9:00	2
9/17/2007 9:00	2	10/28/2007 9:00	2	12/8/2007 9:00	2
9/18/2007 9:00	2	10/29/2007 9:00	2	12/9/2007 9:00	2
9/19/2007 9:00	2	10/30/2007 9:00	2	12/10/2007 9:00	2
9/20/2007 9:00	2	10/31/2007 9:00	2	12/11/2007 9:00	2
9/21/2007 9:00	2	11/1/2007 9:00	2	12/12/2007 9:00	2
9/22/2007 9:00	7	11/2/2007 9:00	2	12/13/2007 9:00	2
9/23/2007 9:00	2	11/3/2007 9:00	2	12/14/2007 9:00	2
9/24/2007 9:00	2	11/4/2007 9:00	2	12/15/2007 9:00	2
9/25/2007 9:00	7	11/5/2007 9:00	2	12/16/2007 9:00	2
9/26/2007 9:00	7	11/6/2007 9:00	2	12/17/2007 9:00	2
9/27/2007 9:00	2	11/7/2007 9:00	2	12/18/2007 9:00	2
9/28/2007 9:00	2	11/8/2007 9:00	2	12/19/2007 9:00	2
9/29/2007 9:00	2	11/9/2007 9:00	2	12/20/2007 9:00	2
9/30/2007 9:00	7	11/10/2007 9:00	2	12/21/2007 9:00	2
10/1/2007 9:00	2	11/11/2007 9:00	2	12/22/2007 9:00	2
10/2/2007 9:00	7	11/12/2007 9:00	2	12/23/2007 9:00	2
10/3/2007 9:00	2	11/13/2007 9:00	2	12/24/2007 9:00	2
10/4/2007 9:00	2	11/14/2007 9:00	2	12/25/2007 9:00	2
10/5/2007 9:00	2.2	11/15/2007 9:00	2	12/26/2007 9:00	2
10/6/2007 9:00	2	11/16/2007 9:00	2	12/27/2007 9:00	2
10/7/2007 9:00	2	11/17/2007 9:00	2	12/28/2007 9:00	2
10/8/2007 9:00	7	11/18/2007 9:00	2	12/29/2007 9:00	2
10/9/2007 9:00	7	11/19/2007 9:00	2	12/30/2007 9:00	2
10/10/2007 9:00	7	11/20/2007 9:00	2	12/31/2007 9:00	2
10/11/2007 9:00	2	11/21/2007 9:00	2		
10/12/2007 9:00	2	11/22/2007 9:00	2		
10/13/2007 9:00	2	11/23/2007 9:00	2		
10/14/2007 9:00	2	11/24/2007 9:00	2		

2008					
Date and Time	ET Value	Date and Time	ET Value	Date and Time	ET Value
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1/2/2008 9:00	2	2/12/2008 9:00	2	3/24/2008 9:00	2
1/3/2008 9:00	2	2/13/2008 9:00	2	3/25/2008 9:00	2
1/4/2008 9:00	2	2/14/2008 9:00	2	3/26/2008 9:00	2
1/5/2008 9:00	2	2/15/2008 9:00	2	3/27/2008 9:00	2
1/6/2008 9:00	2	2/16/2008 9:00	2	3/28/2008 9:00	2
1/7/2008 9:00	2	2/17/2008 9:00	2	3/29/2008 9:00	2
1/8/2008 9:00	2	2/18/2008 9:00	2	3/30/2008 9:00	2
1/9/2008 9:00	2	2/19/2008 9:00	2	3/31/2008 9:00	2
1/10/2008 9:00	2	2/20/2008 9:00	2	4/1/2008 9:00	2
1/11/2008 9:00	2	2/21/2008 9:00	2	4/2/2008 9:00	2
1/12/2008 9:00	2	2/22/2008 9:00	2	4/3/2008 9:00	2
1/13/2008 9:00	2	2/23/2008 9:00	2	4/4/2008 9:00	2.5
1/14/2008 9:00	2	2/24/2008 9:00	2	4/5/2008 9:00	2
1/15/2008 9:00	2	2/25/2008 9:00	2	4/6/2008 9:00	2.5
1/16/2008 9:00	2	2/26/2008 9:00	2	4/7/2008 9:00	2
1/17/2008 9:00	2	2/27/2008 9:00	2	4/8/2008 9:00	2.6
1/18/2008 9:00	2	2/28/2008 9:00	2	4/9/2008 9:00	2
1/19/2008 9:00	7	2/29/2008 9:00	2	4/10/2008 9:00	2
1/20/2008 9:00	2	3/1/2008 9:00	2	4/11/2008 9:00	2
1/21/2008 9:00	2	3/2/2008 9:00	2	4/12/2008 9:00	2
1/22/2008 9:00	2	3/3/2008 9:00	2	4/13/2008 9:00	2
1/23/2008 9:00	3.5	3/4/2008 9:00	2	4/14/2008 9:00	2
1/24/2008 9:00	2	3/5/2008 9:00	2	4/15/2008 9:00	2
1/25/2008 9:00	2	3/6/2008 9:00	2	4/16/2008 9:00	2.5
1/26/2008 9:00	2	3/7/2008 9:00	2	4/17/2008 9:00	2.5
1/27/2008 9:00	2	3/8/2008 9:00	2	4/18/2008 9:00	2
1/28/2008 9:00	2	3/9/2008 9:00	2	4/19/2008 9:00	3.4
1/29/2008 9:00	2	3/10/2008 9:00	2	4/20/2008 9:00	2
1/30/2008 9:00	2	3/11/2008 9:00	2	4/21/2008 9:00	2
1/31/2008 9:00	2	3/12/2008 9:00	2	4/22/2008 9:00	2.5
2/1/2008 9:00	2	3/13/2008 9:00	2	4/23/2008 9:00	2
2/2/2008 9:00	2	3/14/2008 9:00	2	4/24/2008 9:00	7
2/3/2008 9:00	2	3/15/2008 9:00	2	4/25/2008 9:00	2
2/4/2008 9:00	2	3/16/2008 9:00	2	4/26/2008 9:00	2
2/5/2008 9:00	2	3/17/2008 9:00	2	4/27/2008 9:00	7
2/6/2008 9:00	2	3/18/2008 9:00	2	4/28/2008 9:00	2
2/7/2008 9:00	2	3/19/2008 9:00	2	4/29/2008 9:00	2
2/8/2008 9:00	2	3/20/2008 9:00	2	4/30/2008 9:00	2
2/9/2008 9:00	2	3/21/2008 9:00	2	5/1/2008 9:00	2
2/10/2008 9:00	2	3/22/2008 9:00	2	5/2/2008 9:00	2

Date and Time	ET Value	Date and Time	ET Value	Date and Time	ET Value
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5/5/2008 9:00	2	6/15/2008 9:00	7	7/26/2008 9:00	2
5/6/2008 9:00	2.5	6/16/2008 9:00	2	7/27/2008 9:00	4.3
5/7/2008 9:00	2.5	6/17/2008 9:00	2	7/28/2008 9:00	2
5/8/2008 9:00	2.5	6/18/2008 9:00	7	7/29/2008 9:00	2.6
5/9/2008 9:00	2.5	6/19/2008 9:00	2	7/30/2008 9:00	7
5/10/2008 9:00	2.5	6/20/2008 9:00	7	7/31/2008 9:00	7
5/11/2008 9:00	2.5	6/21/2008 9:00	7	8/1/2008 9:00	3
5/12/2008 9:00	2.5	6/22/2008 9:00	7	8/2/2008 9:00	2
5/13/2008 9:00	3	6/23/2008 9:00	2	8/3/2008 9:00	2
5/14/2008 9:00	3	6/24/2008 9:00	2	8/4/2008 9:00	2.8
5/15/2008 9:00	3	6/25/2008 9:00	5.9	8/5/2008 9:00	7
5/16/2008 9:00	7	6/26/2008 9:00	2	8/6/2008 9:00	2
5/17/2008 9:00	2.5	6/27/2008 9:00	2	8/7/2008 9:00	2
5/18/2008 9:00	2.5	6/28/2008 9:00	2	8/8/2008 9:00	2
5/19/2008 9:00	2.5	6/29/2008 9:00	2	8/9/2008 9:00	2
5/20/2008 9:00	2	6/30/2008 9:00	2	8/10/2008 9:00	7
5/21/2008 9:00	2	7/1/2008 9:00	2	8/11/2008 9:00	2
5/22/2008 9:00	7	7/2/2008 9:00	2	8/12/2008 9:00	7
5/23/2008 9:00	7	7/3/2008 9:00	2	8/13/2008 9:00	2.7
5/24/2008 9:00	2	7/4/2008 9:00	2	8/14/2008 9:00	2
5/25/2008 9:00	2	7/5/2008 9:00	2	8/15/2008 9:00	2
5/26/2008 9:00	2	7/6/2008 9:00	7	8/16/2008 9:00	2
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5/29/2008 9:00	2	7/9/2008 9:00	7	8/19/2008 9:00	2
5/30/2008 9:00	2	7/10/2008 9:00	2	8/20/2008 9:00	2
5/31/2008 9:00	7	7/11/2008 9:00	2	8/21/2008 9:00	2
6/1/2008 9:00	2	7/12/2008 9:00	3.8	8/22/2008 9:00	3.6
6/2/2008 9:00	7	7/13/2008 9:00	2	8/23/2008 9:00	2
6/3/2008 9:00	2	7/14/2008 9:00	2	8/24/2008 9:00	2
6/4/2008 9:00	2	7/15/2008 9:00	2	8/25/2008 9:00	2
6/5/2008 9:00	2	7/16/2008 9:00	2	8/26/2008 9:00	2
6/6/2008 9:00	3.7	7/17/2008 9:00	7	8/27/2008 9:00	7
6/7/2008 9:00	2.5	7/18/2008 9:00	7	8/28/2008 9:00	3.8
6/8/2008 9:00	2	7/19/2008 9:00	7	8/29/2008 9:00	7
6/9/2008 9:00	7	7/20/2008 9:00	7	8/30/2008 9:00	7
6/10/2008 9:00	2	7/21/2008 9:00	7	8/31/2008 9:00	7
6/11/2008 9:00	5.2	7/22/2008 9:00	7	9/1/2008 9:00	2
6/12/2008 9:00	2.5	7/23/2008 9:00	3.7	9/2/2008 9:00	2

Date and Time	ET Value	Date and Time	ET Value	Date and Time	ET Value
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9/5/2008 9:00	2	10/16/2008 9:00	2	11/26/2008 9:00	2
9/6/2008 9:00	2	10/17/2008 9:00	2	11/27/2008 9:00	2
9/7/2008 9:00	2	10/18/2008 9:00	2	11/28/2008 9:00	2
9/8/2008 9:00	2	10/19/2008 9:00	2	11/29/2008 9:00	2
9/9/2008 9:00	2	10/20/2008 9:00	2	11/30/2008 9:00	2
9/10/2008 9:00	2	10/21/2008 9:00	2	12/1/2008 9:00	2
9/11/2008 9:00	2	10/22/2008 9:00	2	12/2/2008 9:00	2
9/12/2008 9:00	4.2	10/23/2008 9:00	2	12/3/2008 9:00	2
9/13/2008 9:00	6	10/24/2008 9:00	2	12/4/2008 9:00	2
9/14/2008 9:00	7	10/25/2008 9:00	2	12/5/2008 9:00	2
9/15/2008 9:00	7	10/26/2008 9:00	2	12/6/2008 9:00	2
9/16/2008 9:00	3.2	10/27/2008 9:00	2	12/7/2008 9:00	2
9/17/2008 9:00	7	10/28/2008 9:00	2	12/8/2008 9:00	2
9/18/2008 9:00	2	10/29/2008 9:00	2	12/9/2008 9:00	2
9/19/2008 9:00	2	10/30/2008 9:00	2	12/10/2008 9:00	2
9/20/2008 9:00	7	10/31/2008 9:00	2	12/11/2008 9:00	2
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9/22/2008 9:00	2	11/2/2008 9:00	2	12/13/2008 9:00	2
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9/24/2008 9:00	2	11/4/2008 9:00	2	12/15/2008 9:00	2
9/25/2008 9:00	2	11/5/2008 9:00	2	12/16/2008 9:00	2
9/26/2008 9:00	3	11/6/2008 9:00	2	12/17/2008 9:00	2
9/27/2008 9:00	2	11/7/2008 9:00	2	12/18/2008 9:00	2
9/28/2008 9:00	2	11/8/2008 9:00	2	12/19/2008 9:00	2
9/29/2008 9:00	7	11/9/2008 9:00	2	12/20/2008 9:00	2
9/30/2008 9:00	2	11/10/2008 9:00	2	12/21/2008 9:00	2
10/1/2008 9:00	2	11/11/2008 9:00	2	12/22/2008 9:00	2
10/2/2008 9:00	2	11/12/2008 9:00	2	12/23/2008 9:00	2
10/3/2008 9:00	2	11/13/2008 9:00	2	12/24/2008 9:00	2
10/4/2008 9:00	2	11/14/2008 9:00	2	12/25/2008 9:00	2
10/5/2008 9:00	2	11/15/2008 9:00	2	12/26/2008 9:00	2
10/6/2008 9:00	7	11/16/2008 9:00	2	12/27/2008 9:00	2
10/7/2008 9:00	7	11/17/2008 9:00	2	12/28/2008 9:00	2
10/8/2008 9:00	7	11/18/2008 9:00	2	12/29/2008 9:00	2
10/9/2008 9:00	2	11/19/2008 9:00	2	12/30/2008 9:00	2
10/10/2008 9:00	4.8	11/20/2008 9:00	2	12/31/2008 9:00	2
10/11/2008 9:00	2	11/21/2008 9:00	2		
10/12/2008 9:00	2	11/22/2008 9:00	2		
10/13/2008 9:00	2	11/23/2008 9:00	2		

2009					
Date and Time	ET Value	Date and Time	ET Value	Date and Time	ET Value
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1/4/2009 9:00	2	2/14/2009 9:00	2	3/27/2009 9:00	2
1/5/2009 9:00	2	2/15/2009 9:00	2	3/28/2009 9:00	2
1/6/2009 9:00	2	2/16/2009 9:00	2	3/29/2009 9:00	2
1/7/2009 9:00	2	2/17/2009 9:00	2	3/30/2009 9:00	3.8
1/8/2009 9:00	2	2/18/2009 9:00	2	3/31/2009 9:00	5.9
1/9/2009 9:00	2	2/19/2009 9:00	2	4/1/2009 9:00	2
1/10/2009 9:00	2	2/20/2009 9:00	2	4/2/2009 9:00	2
1/11/2009 9:00	2	2/21/2009 9:00	2	4/3/2009 9:00	2
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1/14/2009 9:00	2	2/24/2009 9:00	2	4/6/2009 9:00	2.5
1/15/2009 9:00	2	2/25/2009 9:00	2	4/7/2009 9:00	2
1/16/2009 9:00	2	2/26/2009 9:00	2	4/8/2009 9:00	2.6
1/17/2009 9:00	2	2/27/2009 9:00	2	4/9/2009 9:00	2
1/18/2009 9:00	2.4	2/28/2009 9:00	2	4/10/2009 9:00	2
1/19/2009 9:00	2	3/1/2009 9:00	2	4/11/2009 9:00	2
1/20/2009 9:00	2	3/2/2009 9:00	2	4/12/2009 9:00	2
1/21/2009 9:00	2	3/3/2009 9:00	2	4/13/2009 9:00	2
1/22/2009 9:00	2	3/4/2009 9:00	2	4/14/2009 9:00	2
1/23/2009 9:00	2	3/5/2009 9:00	2	4/15/2009 9:00	2
1/24/2009 9:00	2	3/6/2009 9:00	2	4/16/2009 9:00	2.5
1/25/2009 9:00	2	3/7/2009 9:00	2	4/17/2009 9:00	2.5
1/26/2009 9:00	2	3/8/2009 9:00	2	4/18/2009 9:00	2
1/27/2009 9:00	2	3/9/2009 9:00	2	4/19/2009 9:00	3.4
1/28/2009 9:00	2	3/10/2009 9:00	2	4/20/2009 9:00	2
1/29/2009 9:00	2	3/11/2009 9:00	7	4/21/2009 9:00	2
1/30/2009 9:00	2	3/12/2009 9:00	2	4/22/2009 9:00	2.5
1/31/2009 9:00	2	3/13/2009 9:00	7	4/23/2009 9:00	2
2/1/2009 9:00	2	3/14/2009 9:00	2	4/24/2009 9:00	7
2/2/2009 9:00	2	3/15/2009 9:00	2	4/25/2009 9:00	2
2/3/2009 9:00	2	3/16/2009 9:00	2	4/26/2009 9:00	2
2/4/2009 9:00	2	3/17/2009 9:00	2	4/27/2009 9:00	7
2/5/2009 9:00	2	3/18/2009 9:00	2	4/28/2009 9:00	2
2/6/2009 9:00	2	3/19/2009 9:00	7	4/29/2009 9:00	2
2/7/2009 9:00	2	3/20/2009 9:00	2	4/30/2009 9:00	2
2/8/2009 9:00	2	3/21/2009 9:00	2	5/1/2009 9:00	2
2/9/2009 9:00	2	3/22/2009 9:00	2	5/2/2009 9:00	2
2/10/2009 9:00	2	3/23/2009 9:00	7	5/3/2009 9:00	2

Date and Time	ET Value	Date and Time	ET Value	Date and Time	ET Value
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5/7/2009 9:00	2.5	6/17/2009 9:00	2	7/28/2009 9:00	2
5/8/2009 9:00	2.5	6/18/2009 9:00	7	7/29/2009 9:00	2.6
5/9/2009 9:00	2.5	6/19/2009 9:00	2	7/30/2009 9:00	7
5/10/2009 9:00	2.5	6/20/2009 9:00	7	7/31/2009 9:00	7
5/11/2009 9:00	2.5	6/21/2009 9:00	7	8/1/2009 9:00	3
5/12/2009 9:00	2.5	6/22/2009 9:00	7	8/2/2009 9:00	2
5/13/2009 9:00	3	6/23/2009 9:00	2	8/3/2009 9:00	2
5/14/2009 9:00	3	6/24/2009 9:00	2	8/4/2009 9:00	2.8
5/15/2009 9:00	3	6/25/2009 9:00	5.9	8/5/2009 9:00	7
5/16/2009 9:00	7	6/26/2009 9:00	2	8/6/2009 9:00	2
5/17/2009 9:00	2.5	6/27/2009 9:00	2	8/7/2009 9:00	2
5/18/2009 9:00	2.5	6/28/2009 9:00	2	8/8/2009 9:00	2
5/19/2009 9:00	2.5	6/29/2009 9:00	2	8/9/2009 9:00	2
5/20/2009 9:00	2	6/30/2009 9:00	2	8/10/2009 9:00	7
5/21/2009 9:00	2	7/1/2009 9:00	2	8/11/2009 9:00	2
5/22/2009 9:00	7	7/2/2009 9:00	2	8/12/2009 9:00	7
5/23/2009 9:00	7	7/3/2009 9:00	2	8/13/2009 9:00	2.7
5/24/2009 9:00	2	7/4/2009 9:00	2	8/14/2009 9:00	2
5/25/2009 9:00	2	7/5/2009 9:00	2	8/15/2009 9:00	2
5/26/2009 9:00	2	7/6/2009 9:00	7	8/16/2009 9:00	2
5/27/2009 9:00	2	7/7/2009 9:00	7	8/17/2009 9:00	2
5/28/2009 9:00	7	7/8/2009 9:00	7	8/18/2009 9:00	3.7
5/29/2009 9:00	2	7/9/2009 9:00	7	8/19/2009 9:00	2
5/30/2009 9:00	2	7/10/2009 9:00	2	8/20/2009 9:00	2
5/31/2009 9:00	7	7/11/2009 9:00	2	8/21/2009 9:00	2
6/1/2009 9:00	2	7/12/2009 9:00	3.8	8/22/2009 9:00	3.6
6/2/2009 9:00	7	7/13/2009 9:00	2	8/23/2009 9:00	2
6/3/2009 9:00	2	7/14/2009 9:00	2	8/24/2009 9:00	2
6/4/2009 9:00	2	7/15/2009 9:00	2	8/25/2009 9:00	2
6/5/2009 9:00	2	7/16/2009 9:00	2	8/26/2009 9:00	2
6/6/2009 9:00	3.7	7/17/2009 9:00	7	8/27/2009 9:00	7
6/7/2009 9:00	2.5	7/18/2009 9:00	7	8/28/2009 9:00	3.8
6/8/2009 9:00	2	7/19/2009 9:00	7	8/29/2009 9:00	7
6/9/2009 9:00	7	7/20/2009 9:00	7	8/30/2009 9:00	7
6/10/2009 9:00	2	7/21/2009 9:00	7	8/31/2009 9:00	7
6/11/2009 9:00	5.2	7/22/2009 9:00	7	9/1/2009 9:00	2
6/12/2009 9:00	2.5	7/23/2009 9:00	3.7	9/2/2009 9:00	2
6/13/2009 9:00	7	7/24/2009 9:00	2	9/3/2009 9:00	2

Date and Time	ET Value	Date and Time	ET Value	Date and Time	ET Value
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9/7/2009 9:00	2	10/18/2009 9:00	2	11/28/2009 9:00	2
9/8/2009 9:00	2	10/19/2009 9:00	2	11/29/2009 9:00	2
9/9/2009 9:00	2	10/20/2009 9:00	2	11/30/2009 9:00	2
9/10/2009 9:00	2	10/21/2009 9:00	2	12/1/2009 9:00	2
9/11/2009 9:00	2	10/22/2009 9:00	2	12/2/2009 9:00	2
9/12/2009 9:00	4.2	10/23/2009 9:00	2	12/3/2009 9:00	2
9/13/2009 9:00	6	10/24/2009 9:00	2	12/4/2009 9:00	2
9/14/2009 9:00	7	10/25/2009 9:00	2	12/5/2009 9:00	2
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9/16/2009 9:00	3.2	10/27/2009 9:00	2	12/7/2009 9:00	2
9/17/2009 9:00	7	10/28/2009 9:00	2	12/8/2009 9:00	2
9/18/2009 9:00	2	10/29/2009 9:00	2	12/9/2009 9:00	2
9/19/2009 9:00	2	10/30/2009 9:00	2	12/10/2009 9:00	2
9/20/2009 9:00	7	10/31/2009 9:00	2	12/11/2009 9:00	2
9/21/2009 9:00	2	11/1/2009 9:00	2	12/12/2009 9:00	2
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9/24/2009 9:00	2	11/4/2009 9:00	2	12/15/2009 9:00	2
9/25/2009 9:00	2	11/5/2009 9:00	2	12/16/2009 9:00	2
9/26/2009 9:00	3	11/6/2009 9:00	2	12/17/2009 9:00	2
9/27/2009 9:00	2	11/7/2009 9:00	2	12/18/2009 9:00	2
9/28/2009 9:00	2	11/8/2009 9:00	2	12/19/2009 9:00	2
9/29/2009 9:00	7	11/9/2009 9:00	2	12/20/2009 9:00	2
9/30/2009 9:00	2	11/10/2009 9:00	2	12/21/2009 9:00	2
10/1/2009 9:00	2	11/11/2009 9:00	2	12/22/2009 9:00	2
10/2/2009 9:00	2	11/12/2009 9:00	2	12/23/2009 9:00	2
10/3/2009 9:00	2	11/13/2009 9:00	2	12/24/2009 9:00	2
10/4/2009 9:00	2	11/14/2009 9:00	2	12/25/2009 9:00	2
10/5/2009 9:00	2	11/15/2009 9:00	2	12/26/2009 9:00	2
10/6/2009 9:00	7	11/16/2009 9:00	2	12/27/2009 9:00	2
10/7/2009 9:00	7	11/17/2009 9:00	2	12/28/2009 9:00	2
10/8/2009 9:00	7	11/18/2009 9:00	2	12/29/2009 9:00	2
10/9/2009 9:00	2	11/19/2009 9:00	2	12/30/2009 9:00	2
10/10/2009 9:00	4.8	11/20/2009 9:00	2	12/31/2009 9:00	2
10/11 /2009 9:00	2	11/21/2009 9:00	2		
10/12/2009 9:00	2	11/22/2009 9:00	2		
10/13/2009 9:00	2	11/23/2009 9:00	2		
10/14/2009 9:00	2	11/24/2009 9:00	2		

2010					
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1/4/2010 9:00	2	2/14/2010 9:00	2	3/27/2010 9:00	2
1/5/2010 9:00	2	2/15/2010 9:00	2	3/28/2010 9:00	2
1/6/2010 9:00	2	2/16/2010 9:00	2	3/29/2010 9:00	2
1/7/2010 9:00	2	2/17/2010 9:00	2	3/30/2010 9:00	3.8
1/8/2010 9:00	2	2/18/2010 9:00	2	3/31/2010 9:00	5.9
1/9/2010 9:00	2	2/19/2010 9:00	2	4/1/2010 9:00	2
1/10/2010 9:00	2	2/20/2010 9:00	2	4/2/2010 9:00	2
1/11/2010 9:00	2	2/21/2010 9:00	2	4/3/2010 9:00	2
1/12/2010 9:00	2	2/22/2010 9:00	2	4/4/2010 9:00	2.5
1/13/2010 9:00	2	2/23/2010 9:00	2	4/5/2010 9:00	2
1/14/2010 9:00	2	2/24/2010 9:00	2	4/6/2010 9:00	2.5
1/15/2010 9:00	2	2/25/2010 9:00	2	4/7/2010 9:00	2
1/16/2010 9:00	2	2/26/2010 9:00	2	4/8/2010 9:00	2.6
1/17/2010 9:00	2	2/27/2010 9:00	2	4/9/2010 9:00	2
1/18/2010 9:00	2.4	2/28/2010 9:00	2	4/10/2010 9:00	2
1/19/2010 9:00	2	3/1/2010 9:00	2	4/11/2010 9:00	2
1/20/2010 9:00	2	3/2/2010 9:00	2	4/12/2010 9:00	2
1/21/2010 9:00	2	3/3/2010 9:00	2	4/13/2010 9:00	2
1/22/2010 9:00	2	3/4/2010 9:00	2	4/14/2010 9:00	2
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1/24/2010 9:00	2	3/6/2010 9:00	2	4/16/2010 9:00	2.5
1/25/2010 9:00	2	3/7/2010 9:00	2	4/17/2010 9:00	2.5
1/26/2010 9:00	2	3/8/2010 9:00	2	4/18/2010 9:00	2
1/27/2010 9:00	2	3/9/2010 9:00	2	4/19/2010 9:00	3.4
1/28/2010 9:00	2	3/10/2010 9:00	2	4/20/2010 9:00	2
1/29/2010 9:00	2	3/11/2010 9:00	7	4/21/2010 9:00	2
1/30/2010 9:00	2	3/12/2010 9:00	2	4/22/2010 9:00	2.5
1/31/2010 9:00	2	3/13/2010 9:00	7	4/23/2010 9:00	2
2/1/2010 9:00	2	3/14/2010 9:00	2	4/24/2010 9:00	7
2/2/2010 9:00	2	3/15/2010 9:00	2	4/25/2010 9:00	2
2/3/2010 9:00	2	3/16/2010 9:00	2	4/26/2010 9:00	2
2/4/2010 9:00	2	3/17/2010 9:00	2	4/27/2010 9:00	7
2/5/2010 9:00	2	3/18/2010 9:00	2	4/28/2010 9:00	2
2/6/2010 9:00	2	3/19/2010 9:00	7	4/29/2010 9:00	2
2/7/2010 9:00	2	3/20/2010 9:00	2	4/30/2010 9:00	2
2/8/2010 9:00	2	3/21/2010 9:00	2	5/1/2010 9:00	2
2/9/2010 9:00	2	3/22/2010 9:00	2	5/2/2010 9:00	2
2/10/2010 9:00	2	3/23/2010 9:00	7	5/3/2010 9:00	2

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5/26/2010 9:00	2	7/6/2010 9:00	7	8/16/2010 9:00	2
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6/2/2010 9:00	7	7/13/2010 9:00	2	8/23/2010 9:00	2
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6/6/2010 9:00	3.7	7/17/2010 9:00	7	8/27/2010 9:00	7
6/7/2010 9:00	2.5	7/18/2010 9:00	7	8/28/2010 9:00	3.8
6/8/2010 9:00	2	7/19/2010 9:00	7	8/29/2010 9:00	7
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6/12/2010 9:00	2.5	7/23/2010 9:00	3.7	9/2/2010 9:00	2
6/13/2010 9:00	7	7/24/2010 9:00	2	9/3/2010 9:00	2

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10/2/2010 9:00	2	11/12/2010 9:00	2	12/23/2010 9:00	2
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10/9/2010 9:00	2	11/19/2010 9:00	2	12/30/2010 9:00	2
10/10/2010 9:00	4.8	11/20/2010 9:00	2	12/31/2010 9:00	2
10/11/2010 9:00	2	11/21/2010 9:00	2		
10/12/2010 9:00	2	11/22/2010 9:00	2		
10/13/2010 9:00	2	11/23/2010 9:00	2		
10/14/2010 9:00	2	11/24/2010 9:00	2		

2011					
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1/5/2011 9:00	2	2/15/2011 9:00	2	3/28/2011 9:00	2
1/6/2011 9:00	2	2/16/2011 9:00	2	3/29/2011 9:00	2
1/7/2011 9:00	2	2/17/2011 9:00	2	3/30/2011 9:00	3.8
1/8/2011 9:00	2	2/18/2011 9:00	2	3/31/2011 9:00	5.9
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1/16/2011 9:00	2	2/26/2011 9:00	2	4/8/2011 9:00	2.6
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1/30/2011 9:00	2	3/12/2011 9:00	2	4/22/2011 9:00	2.5
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2/8/2011 9:00	2	3/21/2011 9:00	2	5/1/2011 9:00	2
2/9/2011 9:00	2	3/22/2011 9:00	2	5/2/2011 9:00	2
2/10/2011 9:00	2	3/23/2011 9:00	7	5/3/2011 9:00	2

Date and Time	ET Value	Date and Time	ET Value	Date and Time	ET Value
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5/6/2011 9:00	2.5	6/16/2011 9:00	2	7/27/2011 9:00	4.3
5/7/2011 9:00	2.5	6/17/2011 9:00	2	7/28/2011 9:00	2
5/8/2011 9:00	2.5	6/18/2011 9:00	7	7/29/2011 9:00	2.6
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5/13/2011 9:00	3	6/23/2011 9:00	2	8/3/2011 9:00	2
5/14/2011 9:00	3	6/24/2011 9:00	2	8/4/2011 9:00	2.8
5/15/2011 9:00	3	6/25/2011 9:00	5.9	8/5/2011 9:00	7
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5/17/2011 9:00	2.5	6/27/2011 9:00	2	8/7/2011 9:00	2
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5/26/2011 9:00	2	7/6/2011 9:00	7	8/16/2011 9:00	2
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6/9/2011 9:00	7	7/20/2011 9:00	7	8/30/2011 9:00	7
6/10/2011 9:00	2	7/21/2011 9:00	7	8/31/2011 9:00	7
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6/12/2011 9:00	2.5	7/23/2011 9:00	3.7	9/2/2011 9:00	2
6/13/2011 9:00	7	7/24/2011 9:00	2	9/3/2011 9:00	2

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9/17/2011 9:00	7	10/28/2011 9:00	2	12/8/2011 9:00	2
9/18/2011 9:00	2	10/29/2011 9:00	2	12/9/2011 9:00	2
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10/2/2011 9:00	2	11/12/2011 9:00	2	12/23/2011 9:00	2
10/3/2011 9:00	2	11/13/2011 9:00	2	12/24/2011 9:00	2
10/4/2011 9:00	2	11/14/2011 9:00	2	12/25/2011 9:00	2
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10/13/2011 9:00	2	11/23/2011 9:00	2		
10/14/2011 9:00	2	11/24/2011 9:00	2		

Appendix- 4

Table 4.1 Pumping test data of five Upazilas in Chapai Nawabganj district.

Time	Actual drawdown (ft)				
	Nawabganj	Nachole	Shibganj	Bholahat	Gomastapur
00mn	21.22	10.97	15.42	8.98	17.80
05mn	20.09	10.18	14.92	8.68	17.30
10mn	20.12	10.20	14.93	8.69	17.32
15mn	20.16	10.22	14.94	8.69	17.33
20mn	20.20	10.24	14.94	8.70	17.34
30mn	20.24	10.27	14.95	8.70	17.35
40mn	20.27	10.30	14.95	8.71	17.35
50mn	20.30	10.32	14.96	8.71	17.36
60mn	20.33	10.33	14.97	8.72	17.36
75mn	20.35	10.34	14.97	8.72	17.37
90mn	20.37	10.35	14.98	8.73	17.37
120mn	20.40	10.38	14.99	8.74	17.38
150mn	20.43	10.40	15.00	8.75	17.39
180mn	20.46	10.42	15.00	8.76	17.40
210mn	20.48	10.43	15.00	8.76	17.40
240mn	20.49	10.44	15.00	8.76	17.40

Publications from this work

Article in Journal

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