CHAPTER ONE

INTRODUCTION

1.1. Background

Water, a basic need for human life and also for the survival of all life system, is one of the prime elements that sustain life on the earth. An integral part of human existence is the use of water as old as civilization itself. Water is used for subsistence as well as a medium for human endeavor in many forms. Nepal is considered second rich country in the world possessing about 2.27% of the world water resources (CBS, 1993). The major sources of water are glaciers, snow melts, rainfall and ground water.

Groundwater has been extensively used in Kathmandu Valley through dug wells, ponds and dhunge dharas (stone spouts) since ancient period. Shallow groundwater was tapped through dug wells and dhunge dharas. Rapid urbanization and increasing demand have however put enormous stress on the traditional water supply system especially as current municipal water supply barely fulfills 25% of the demand. Even in those days, recharge ponds were made and water was brought from the valley rims through long canals to recharge the system. As many of the traditional sources have been lost or encroached during urbanization process, it has become extremely necessary to reintroduce or revitalize the tradional water recharge system as shallow groundwater system may be the only source of water supply in future.

1.2. The Study Area

Kathmandu Valley, an oval-shaped intermountain valley, lies in the Lesser Himalaya of Central Nepal, stretching about 30 Km in east-west and about 25 Km in north-south direction covering an area of about 650 Km^2. Kathmandu Valley has an average altitude of

1350 m above the mean sea level. About 400 Km^2 areas out of 650 Km^2, is the valley floor and remaining area of 250 Km^2 is the surrounding hills. It includes five major municipalities namely Kathmandu, Lalitpur, Bhaktapur, Thimi and Kirtipur. In Kathmandu valley, particularly its northern side consisting of sediments of Gorkarna Formation and Tokha Formation etc have usually high recharge rate while sediments in Kalimati Formation, which lies in southern part of Kathmandu valley consists of fine grained sediment with mostly clay.

The study area constitutes most of the core area of Lalitpur Sub-Metropolitan City (LSMC) mainly around and inside the ring road in the east, south and west. In the north, the study area is bounded by Bagmati River. Lalitpur Sub-Metropolitan City is located in the south-western part of Kathmandu Valley, is about 8 km south of central Kathmandu (Capital of Nepal) and is situated on the high land or terraces across Bagmati River. Lalitpur Sub-Metropolitan City known for its traditional water resource where dug wells are probably the oldest methods of using local water resources which are still in extensive use to fulfill the current demand of water supply.. The city has preserved a large number of traditional dug wells from Lichchhavi Period (500-800A.D.) to the present day. Therefore, the importance of this study was aroused for providing quality and quantity water supply to the citizens in the Lalitpur Sub-Metropolitan City area, Fig.1.1.

The study area lies on the terrace which gently slopes to the north. The area encompasses most of the area of the administrative wards nos.1 to 22 (altogether 22 wards). The study area consists of mainly gravel and sandy gravel lying on the top of basically fined grained layer of Kalimati clay. Uncontrolled and haphazard urban growth, insufficient municipal water supply, increase in economic activities, changes in life style of the people, lack of enforcement of rules and regulations have resulted in mushrooming of all types of wells tapping groundwater resulting in extensive groundwater mining. High abstraction of groundwater from shallow aquifers has dried up many old dug wells and dhunge dharas depriving many inhabitants from their only source of water.

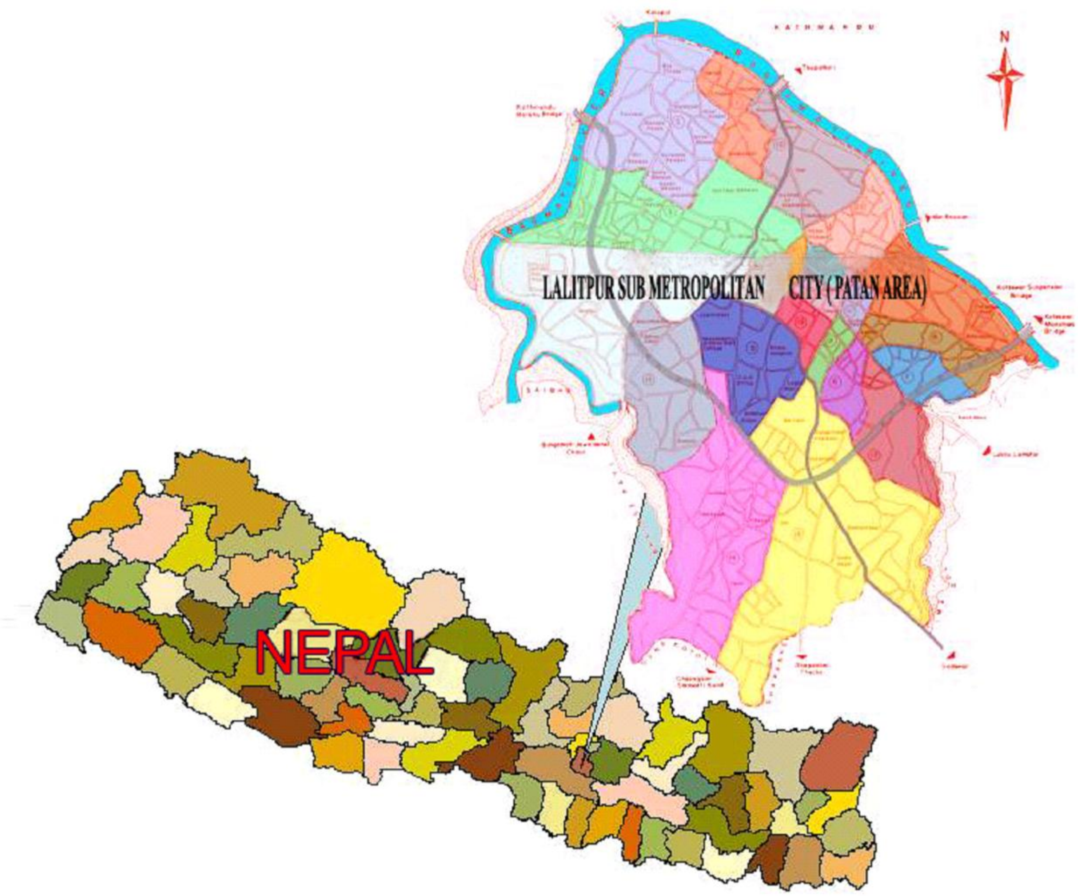

Fig. 1.1: Location Map of Study Area (Lalitpur Sub-Metropolitan City)

1.3. Geomorphology and Topography

Kathmandu Valley consists mainly of alluvial plains, alluvial and colluvial fans, fluvial and lacustrine terraces, and steep to very steep sloping mountains. Two major geomorphic units are the valley floor and the surrounding hills. The valley floor is gently sloping towards the centre and is dissected in the radial direction by the network of rivers giving rise to various separate landmasses with steep slope or scarp faces along the sides. The heights of this scarp are generally 10-20 m and the width extends to some hundreds of meters. The hills surrounding the valley rise steeply on all sides. with Shivapuri Lekh (2732 m) in the north, Nagarkot (2166 m) in the east, Phulchauki (2765 m) in the south and Chandragiri (2550 m) in the west.

The study area consists of flat to gentle slope topography and slope towards northwest direction. The maximum elevation located at Sanepa area and minimum elevation at Bagmati River. The study area exhibits diversity in topography from steep slope (Jawalakhel area) to flat terraces of Kupondole near Bagmati River. The altitude ranges from 1250m to 1350m. (Toposheet No.278506A, Department of Survey)

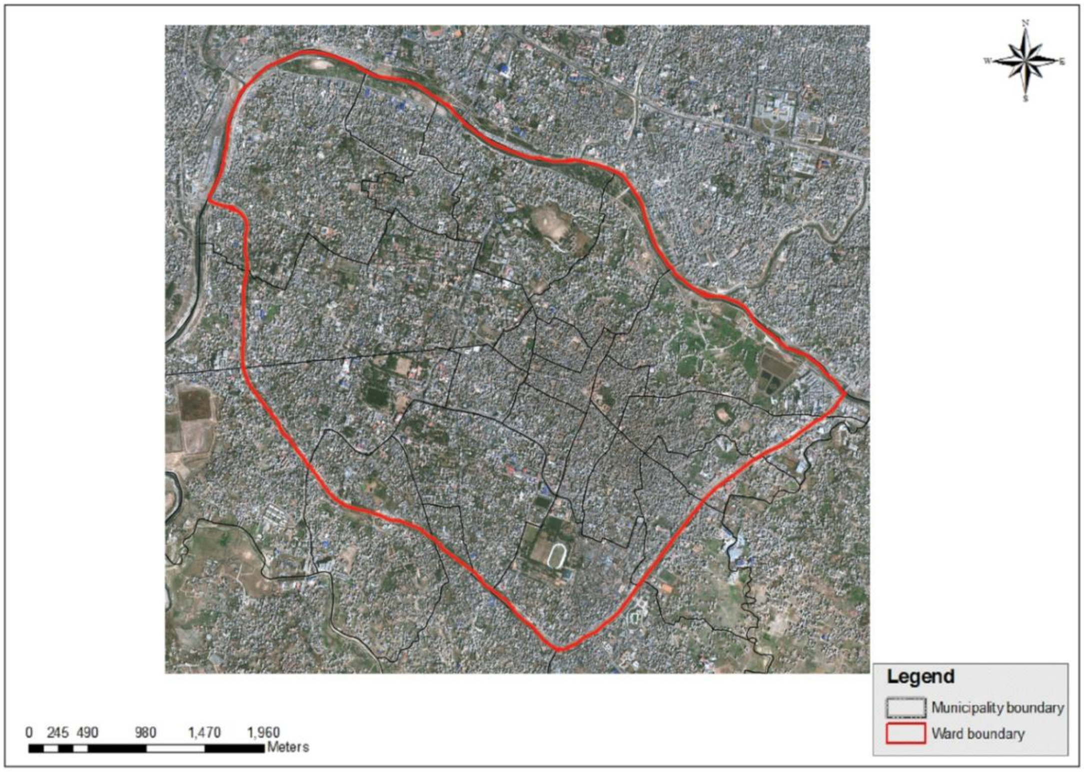

Fig. 1.2: Overall View of Study Area (Source Google Earth)

1.4. Climate and Rainfall

Kathmandu Valley lies in the sub-tropical region and is characterized by warm and temperate climate. The average annual temperature may reach up to the maximum of about 26.2^{o}C and minimum of about 10.6^{o}C within the Kathmandu Valley (DOHM). 80% of the annual rainfall occurs from June through September during the monsoon season. Rainfall varies substantially according to the altitude, the total rain on the basin floor is about 1300 mm while that on the slopes of the surrounding hills goes up to 3000 mm.

1.5. Drainage

Bagmati River is the main drainage of the Kathmandu Valley, which originates from the Shivapuri Lekh (Baghdwar) situated to the north of the valley and it drains out all of the surface water of the valley through the only one exit along the southwestern edge of the valley at Chobhar gorge. The final outlet of the river is near the Katuwal Daha where the altitude of river bed is only 1220m.

Major tributaries of the Bagmati River are the Bishnumati (flows N to S), the Manohara (flows NE to SW), the Dhobi Khola (flows N to S), the Hanumante (flows E to W), the Godawari (flows S to N), the Nakhu Khola (flows S to N), the Kodku Khola (flows S to N), the Balkhu Khola (flows NW to SE) and the Bosan Khola (flows NW to SE). The overall drainage pattern forms a typical example of the centripetal drainage system in the world and it is spread over an area of about 585 sq. Km (JICA, 1990. All the tributaries trending in different directions drain inwards to the center of the valley and join to the Bagmati River.

1.6. Landuse Map of Lalitpur Sub-metropolitan city

The topographical survey 2006 shows that as per land use, the highest percentage (60.48) consisists of residential area and lowest percentage (0.15) by forest land. The landuse map with the datas are given in (Table 1.1) and Fig1.3 and Fig. 1.4:

Table 1.1: Landuse pattern of Lalitpur Sub metropolitan city

Landuse Type	Area (sq.km)	Area (%)
Agriculture	3.688	24.25
Forest	0.022	0.15
Industrial	0.028	0.18
Institutional	0.968	6.37
Military	0.169	1.11
Mixed residential/Commercial	0.176	1.16
Open space	0.154	1.02
Planning Area	0.109	0.72
Public utilities	0.258	1.69
Residential	9.195	60.48
Water body	0.437	2.87

(Source: Topo Map 2006 A.D.)

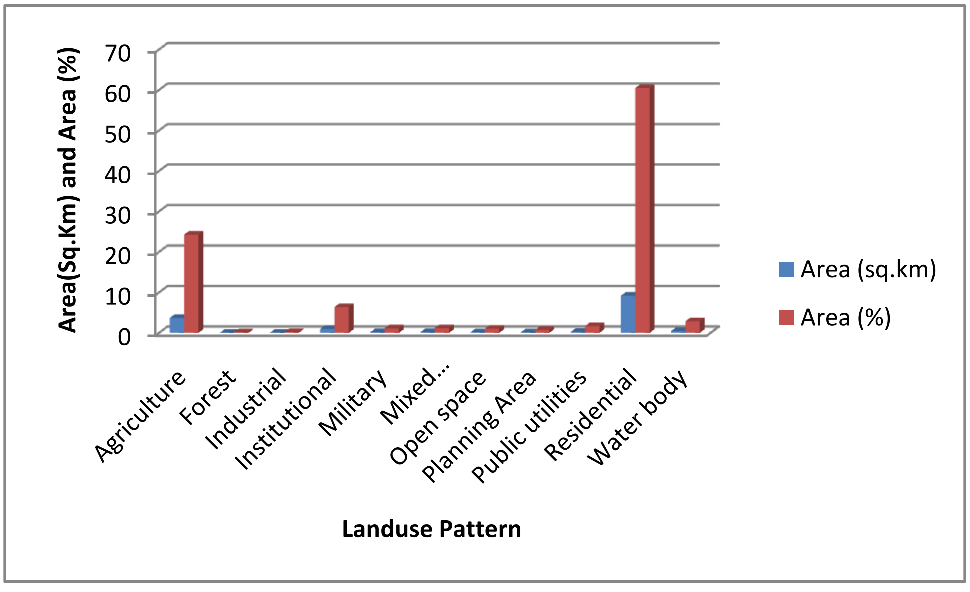

Fig. 1.3: Bar diagram of Landuse Pattern of Lalitpur Sub metropolitan city

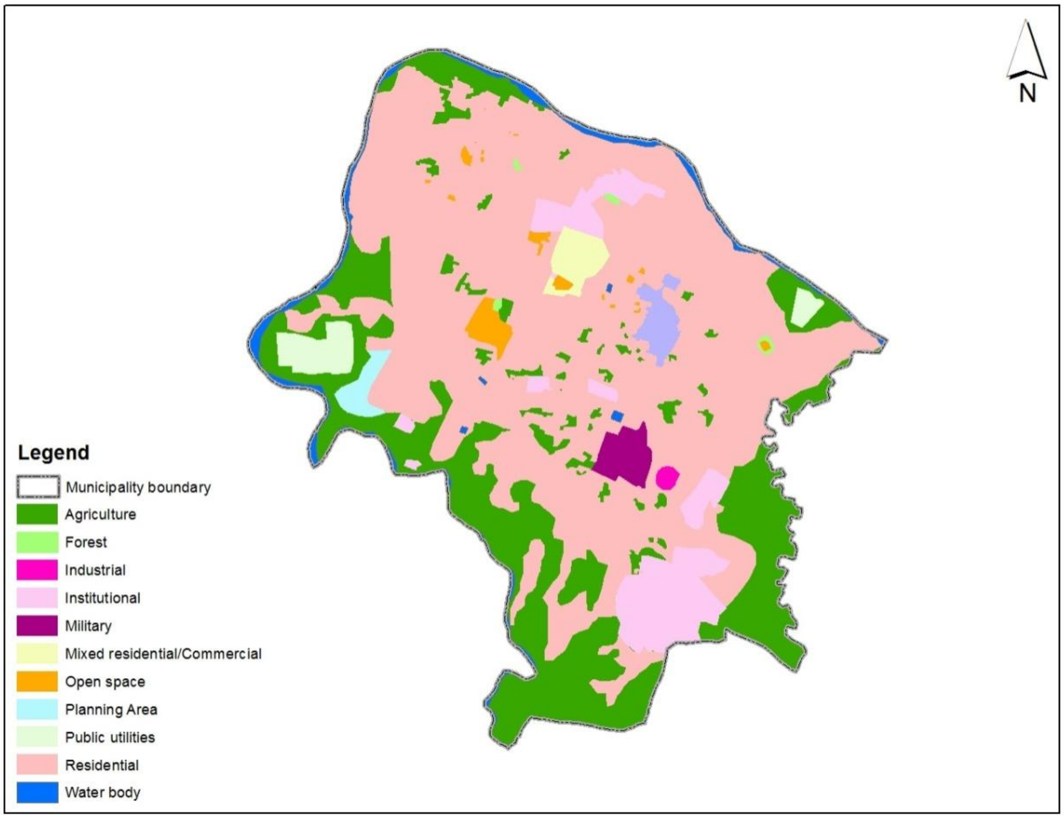

Fig.1.4: Landuse Map of Lalitpur Sub-Metropolitan City (Source Topo Map 2006 A.D.

1.7. Objectives

The objective of the study carried out was to prepare depth to gravel mapping for effective design of rainwater recharge within Lalitpur Sub-metropolis and assess the potential impact on groundwater quality.

Specific objectives are:

1. To identify the potential recharge locations which could be used for community or household recharge.

The recharge locations are to be identified based on the followings:

- Subsurface geology of the area
- Size of the catchment area
- Space available for the construction of recharge pits and siltation pits.
- Community support

2. To identify potential monitoring wells around recharge locations to observe impacts from rainwater recharge.

1.8. Scope and Limitation of Study

The groundwater system in the valley is isolated and independent from other groundwater system outside the valley. The only source of groundwater recharge is rainwater that falls in the valley. Similarly recent construction boom has drastically reduced open space needed for recharge. Thus the only option left is to go for artificial recharge. Manuals, textbooks or publications giving a comprehensive coverage of the subject are not sufficiently available. During the field works, the selection of site for augering is the biggest limitation as finding suitable in natural condition for infiltration test and the arrangement of water, time and cost for infiltration test into the wells are other limitation of the study.

1.9. Structure of dissertation

Dissertation includes following chapters: chapter 1 includes introduction, chapter 2 includes geology, hydrogeology of Kathmandu valley and review of the previous works, chapter 3 includes methodology, chapter 4 includes data acquisition, chapter 5 includes data analysis and interpretation, chapter 6 includes conclusion and recommendation.

CHAPTER TWO

GEOLOGY, HYDROGEOLOGY OF KATHMANDU VALLEY AND REVIEW OF THE PREVIOUS WORKS

Kathmandu valley lies in the Midland Zone of the Lesser Himalaya, Central Nepal. Geologically the Kathmandu Valley is composed of mainly two units- the basement rocks surrounding the terrain of the Kathmandu Basin and the Quaternary basin fill sediments overlying the basement rocks.

2.1. Basement Geology

In the regional geological setup, the basement of the Kathmandu Valley comprises the rocks of Phulchauki Group and Partly of the Bhimphedi Group which belongs to the Allocthnous Kathmandu Complex. The basement rock of Kathmandu valley is a part of Kathmandu nappe first recognized by T. Hagen (1969) and later studied in detail by Stöcklin and Bhattarai 1977 and Stöcklin 1980. The Kathmandu Basin is Syn-Tectonic depression formed due to folding and faulting within the Kathmandu Complex. The constituting rock groups of the complex ranges in age between Precambrian to Devonian (Stocklin and Bhattarrai, 1977).

The Northern and North-Eastern parts of the basin is underlain by the basement rocks of granites, gneisses, schist, migmatites of the Shivapuri Gneiss Injection Zone which show greater degree of weathering and thus gives rise to large amount of alluvial and colluvial in the form of cone and fan. The hills to the East and West of the Valley are mainly composed of phyllites, sandstones and limestones and to the South are slates, metasandstones, quartzites, siltstones, shales and crystalline limestone belonging to Paleozoic Phaulchauki Group.

Stratigraphy of the KathmanduValley is divided into two groups- Phulchouki group and Bhimphedi group, which falls in Kathmandu Complex. The bedrocks within the Valley consists the Paleozoic succession of Tistung Formation, Sopyang Formation, Chandargiri Limestone, Chitlang Formation, and Godawari Limestone.

Table 2.1: Stratigraphic subdivisions of the rocks of the Kathmandu Valley and its surroundings (Stöcklin and Bhattarai, 1977; Stöcklin, 1980)

Group	Formation	Main Lithology	Thickness (m)	Age
Phulchauki Group	GodavariLumestone	Crinoidal limestone, dolomitic limestone	300	Devonian
	Chitlang Formation	sandstone, siltstone and violet grey slate	1000	Silurian
	Chandragiri Limestone	finely crystalline limestone	2000	Cambrian to Ordovician
	Sopyang Formation	Argillaceous and marly slate and calc-phyllite	200	Cambrian (?)
	Tistung Formation	metasandstone, siltstone and phyllite	3000	Early Cambrian to Precambrian
--------------------*Transitional Contact*--------------------				
Bhimphedi Group	Markhu Formation	marble, schist with granite intrusion	1000	Precambrian
	Kulekhani Formation	quartzite and schist	2000	Precambrian

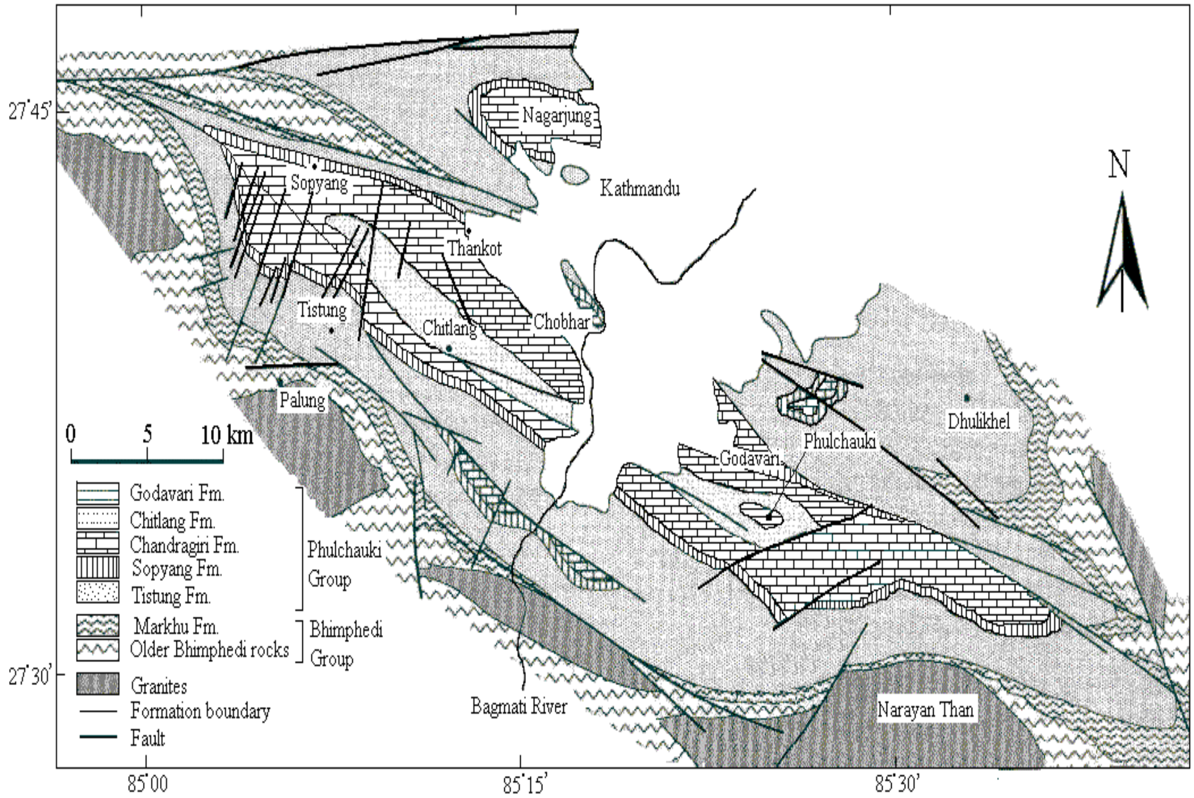

***Fig. 2.1*: Simplified Geological map of Kathmandu valley region (after Stöcklin, 1980)**

2.2. Quaternary Geology

The geology of the Kathmandu valley sediments has been studied by a number workers: Nautiyal and Sharma, 1961; Sharma and Singh, 1966; Yonechi, 1973; Binnie and Partners, 1973; West and Munthe, 1981; Frot and Gupta, 1981; Tuladhar, 1982; Yamanaka, 1984; Yoshida and Igarashi, 1984; Dangol, 1985; Yoshida and Gautam, 1988; Igarashi and Yoshida, 1988; Koirala, 1993; Sah et al., 1997; and recently Sharma et al., 1998.

The first comprehensive works on the basin fill sediments of the valley were carried out by Yoshida and Igarashi (1984). They proposed a stratigraphic division of the valley fill sediments on the basis of the surface geological survey and paleo-magnetic studies.

The KathmanduValley basin consists of thick succession of fluvial and lacustrine sediments of Plio-Pleistocene to Holocene epoch. It mainly constitute unconsolidated to semi consolidated san, gravel, peat, silt, clay and carbonaceous black sticky clay locally known as 'Kalimati' lying unconformably to the Paleozoic rocks of Phulchauki Group and partly of the Bhimphedi Group of the Kathmandu Complex. The thickness of the sediment in the Valley basin is about 550 to 600 m in the central part of the Valley (DMG/BGR, 1998). These sediments are derived from the surrounding hills of the Valley. The individual beds of the fluvio-lacustrine deposits are generally horizontal but gently inclined to about 2-9^{o} due North at the southern margin of the Basin (Sah et al., 1997). The general sediment size distribution within the basin shows the coarser detritus along the peripheral parts and relatively finer sediments towards the central part of the basin.

The first Engineering and Environmental Geological Map of the Kathmandu Valley with scale of 1:50,000 were published by Department of Mines and Geology (Shrestha et al., 1998) under the technical cooperation of Federal Institute of Geosciences and Natural Resources, Hannover, Germany. According to this Engineering and Environmental Geological Map of Kathmandu valley, Neocene to Quaternary fluvio-lacustrine deposit of the Valley is divided into Quaternary Unconsolidated sediment and Plio-Pleistocene Slightly Consolidated sediment(Fig.: 2.2).

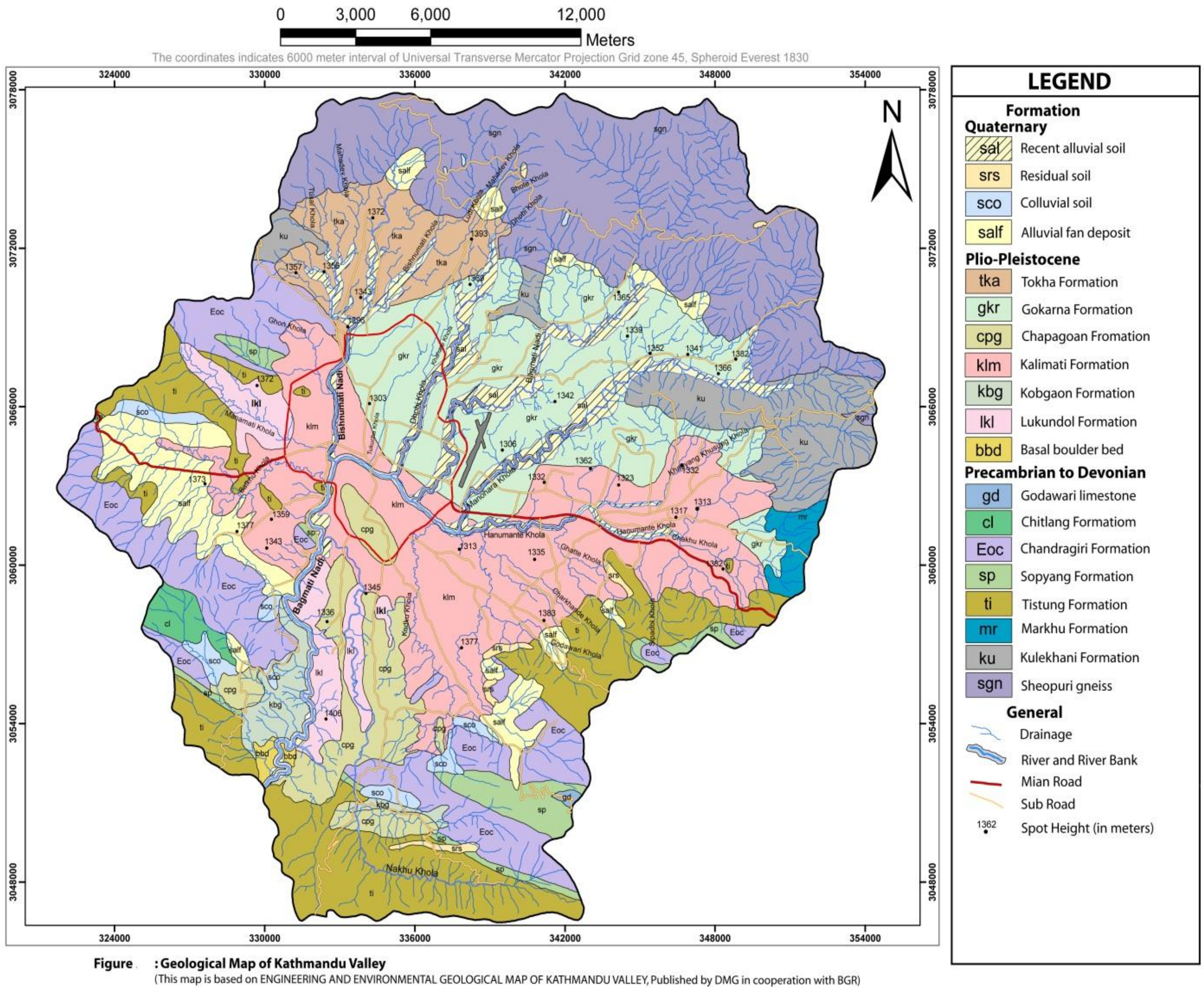

***Fig.2.2*: Geological map of Kathmandu valley (based on Engineering and environmental geological map of Kathmandu valley, DMG))**

Table 2.2: Classification of Quaternary Unconsolidated Sediments of the Kathmandu Valley. (Engineering and Environmental Geological Map of the Kathmandu Valley, Shrestha et al., 1998)

S.N.	Formation	Description
i.	Recent Alluvial Soil (sal)	Recent sediments of flood plains and lower alluvial terraces. In the Northern part, sand and gravel deposits up to boulder size. In central and southern part, clay, sand and fine gravel. Hydro-logically the formation is high potential of groundwater with periodic change of shallow groundwater level, high infiltration and high risk to pollution of groundwater and surface water.
ii.	Residual Soil (srs)	Humicsilty loam to sandy gravels of thickness 1-3 m, at places and occur on slopes. High Infiltration and potential for groundwater.
iii.	Colluvial Soil (sco)	In homogenous deposit at foot slopes with constituents of humic clay silt and sand, at places boulders. Variable thickness>1 m, increasing towards the center of the deposit. High Infiltration and low potential for groundwater.
iv.	Alluvial Fan Deposit (salf)	Gravel, sandy gravel, sand and silt. Thickness increases towards the center of the fan. Finer grained material towards the margin of the fan. High infiltration of surface water and Perched water table may be present.

Table 2.3: Classification of Plio-Pleistocene Slightly Consolidated Sediments of the KathmanduValley. (Engineering and Environmental Geological Map of the Kathmandu Valley, Shrestha et al., 1998)

S.N.	Formations	Description
i.	Tokha Formation (tka)	The formation mainly consists of dark grey clay, brownish grey sand and poorly sorted, sub angular to rounded sandy gravel with occasional peaty clay and lignite layers. The thickness of the formation is up to 200 m or more. This formation may act as good aquifer materials for the groundwater abstraction from shallow depth. The formation is mostly high permeable.
ii.	Gokarna Formation (gkr)	It comprises light grey; fine laminated and poorly graded silty sand, intercalation of clay of variable thickness as well as in upper part Thimi diatomite (1m) present. The total thickness is up to 300 m and more. The sediment of this formation is considered to be fluvio-deltaic facies. In the contest of hydrology, the formation is medium groundwater potential and moderate to high groundwater infiltration.
iii.	Chapagoan Formation (cpg)	It consists of sub-rounded to rounded silty sandy gravel, occasionaly with boulder beds sometime with thin (<1m) clayey silt and silty sand, and at places lignite pockes. The total thickness is up to 110 m. High ground water potential. Moderate to high permeability. Groundwater level is moderately deep and highly vurnerable to groundwater pollution. The formation is potential fro groundwater recharge.
iv.	Kalimati Formation (klm)	The formation is exposed in the central part of the valley around the main cities of Kathmandu, Lalitpur and Bhaktapur. It consisits of grey to dark silty clay and clayey silt, at places calcareous nature and phosphate mineral (vivianite). Organic clay, fine sand beds and peat layers are common. Occasionally lignite seams upto 20m is also occurs. In Kharipati are quartzite and biotite schist boulder beds with sandy gravel and minor clayey and sandy silt layers are present. The total thickness of the formation is 450 m or more. This formation shows purely a lacustrine facies and it acts as an aquiclude or aquitard material having extremely low permeability.
v.	Kobgoan Formation (kbg)	It exposed along the western bank of the BagmatiRiver and NakhuKhola in the southern part of the valley around Yutiki, Pharping, Bansbari and TikaBhairab area. The formation consists of light grey to grey laminated fine sand, occasionally with sndy clay, silty sand and sub rounded to rounded, poorly graded gravel. The thickness is up to 50 m or more. The formation is moderate groundwater potential with moderate to deep groundwater level and has moderate to high permeability.
vi.	Lukundol Formation (lkl)	It is exposed around the Sunakothi, Bungmati, Khokana and Saibhu Bhaisepati area. It is composed of semi-consolidated sandy, clayey silt interbedded with gravel and clayey sand, peat and lignite of upto 3 m thickness. The total thickness of the formation is up to 80 m. The formation is low ground water potential with deep groundwater table and has low permeability.
vii.	Basal Boulder Bed (bbd)	It is the oldest basin fills sediments which unconformably overlie the basement rock of the Valley. The formation is exposed at the south western part of the valley near Katuwal Daha around the Bagmati River. It consists of mainly of compact boulder conglomerate mixed with silt and sand. Boulders are of quartzite, granite, gneiss and meta-sandstone. The thick of this formation is up to 300 m. It has High groundwater potential and permeability.

2.3. HYDROGEOLOGY OF PATAN

A correct understanding the hydrogeology of an area is the prime consequence for successful implementation of any artificial recharge. The hydrogeology of the area is governed by various factors such as the precipitation over the area, rate of infiltration, topography, and geology and drainage networks of the area. In the Valley, the distribution of sediment pattern is diverse and irregular, so aquifer in the valley is in different forms and size. Kathmandu Basin consists of hard rock as the hydrological basement and unconsolidated soft sediments overlying the basement floor- includes, gravel, sand, silt, clay, peat and lignite brought from the surrounding hills in all direction. Whereas, Northern and Northeastern part of the valley were the main source of valley sediments, hence thickness of these valley sediments gradually increases towards South and reaches maximum value in the central and Southern part. The granular deposit in Northern part is generally poorly sorted.

Groundwater found in Kathmandu occurs under unconfined, semi-confined and confined conditions. Upper surface of unconfined groundwater is represented by water table and occurs in shallow aquifer throughout much in the valley. In the central portion where it is underlain by impermeable lacustrine clay, the water table occurs within these impermeable sediments of predominantly silts. The groundwater that occupies these sediments is classified as perched aquifer (Metcalf and Eddy Inc 1999).

2.4. HYDRO-GEOLOGICAL FORMATIONS

a) Formation A

This formation consists of river deposits, talus deposits, fan deposits, and top soil. This formation sometimes forms a shallow aquifer and is found all over the flat plain of the valley. The deposits in the North are sandy, but those in South are predominantly clay and silty clay.

b) Formation B

This formation consists of arnaceous deposits or intermediate types of arnaceous distributed in the Northern part of the valley and form the main aquifer of the Northern part of the Kathmandu valley.

c) Formation C

This formation consists of stiff black clay known as Kalimati clay, which is categorized as argillaceous lacustrine deposits. This impermeable clay formation deposits in center and South of the valley about 200m thick.

d) Formation D

This formation consists of intermediate type of arnaceous and argillaceous deposits of lacustrine deposits which underlies Formation C and forms the deep center aquifer.

e) Formation E

This formation consists of weathered basement rock, which overlies basement rocks. This formation has a very small capability as an aquifer.

f) Formation F

This formation consists of basement rock, and usually forms an aquifuge (hydro-geological basement).

2.5. AQUIFER SETTINGS

Aquifers are the geological formation containing water and that are permeable enough to transmit water through them to yield sufficient quantity of water to the wells and springs. The ground water system of the Kathmandu Valley is considered as a closed and isolated ground water basin, with more or less interconnected aquifers. Depending upon the nature of sediments, the Northern, North-Eastern, deeper parts (>90m) of the Central and Southern provinces fall under good aquifer zones (DMG/BGR, 1998). Geologically, the deep aquifer horizon is the basal gravel bed overlying the basement rock in the Southern part of the Valley and is more or less continuous laterally.

Ramesh Gautam and G. Krishna Rao (1991) classified Kathmandu valley into 4 zones as unconfined aquifer zone, two aquifer zone, confined aquifer zone and no groundwater zone.

a) Unconfined aquifer zone

These types of aquifer zones lie at north of Maharajgunj and Boudha and west of Gorkarna extending upto western and northern foot hills of the valley. The area between the Manohara and Bishnumati Rivers has been classified as interbedded aquifers and treated as an unconfined aquifer zone (Anon, 1988). Medium to coarse grained sand, gravelly sand and silty sand constitute the major aquifer materials forming unconfined aquifers. Unconfined aquifers on the terraces in other parts of the valley, which may have limited potentiality by virtue of finer grain size of sediments, are not considered here.

b) Confined aquifer zone

This aquifer zone lies at South of Maharajgunj and Boudha, and West of Bode and extends up to the Western and Southern boundaries. The aquifer is characterized by the presence of thick Kalimati Clay wich acts as the confining impervious bed. Coarse to very coarse sand, pebble, cobble and gravel are the chief constituents of the confined aquifers which form the main aquifer system within the Valley. The piezometric surface in the confined aquifer area deceases towards the central part of the valley indicating that the flow direction of ground water form periphery towards the middle part of the basin conversing at the center. The piezometric head increases with the depth of the aquifer which is in conformity with the hydraulic principle.

c) Two Aquifer Zone

The central part of the basin consists of two aquifer zones: Shallow aquifer at the top and deep aquifer at the bottom. These two aquifer horizons are separated by thick column of impervious sticky black clay. The shallow aquifers at about 1380 masl in the north central part at Dhobi Khola well field have been tapped for municipal water supply (BGR/DMG, 1998). These shallow perched aquifers are generally composed of clayey sand, silt, gravelly sand with limited local extension. The thickness of the top shallow aquifer increases towards north and northeast up to 44m while it is only 5m thick in the central part. And the thickness of the bottom deep aquifer increases towards central part from 17m to 108m (Gautam and Rao, 1991).

d) Rock Aquifer

The southern, southeastern, and the southwestern part of the valley are covered by inter bedded limestone, sandstone, shale, and siltstone. These rocks are highly jointed, fractured and porous (limestone terrain).When they undergo intense weathering, they become favorable for the formation of groundwater reservoir with the development of underground drainage system. Some industries and institutions have developed the exploration wells in the rock aquifers. The sites in Syuchatar, Saukhel, along the foot hills of Kapan and Tokha are considered to fall within the potential zone of rock aquifers. The areas along the foothills of the southern part of the valley like Pharping, Thapagaun can also be considered as the rock aquifer zone.

2.6. HYDRO-GEOLOGICAL DISTRICTS

Based on physical and chemical properties of the groundwater and geological conditions, JICA 1990 divided the deep part of the Kathmandu basin into three groundwater districts and shown in Fig. 2.3.

a) Northern Groundwater District

This zone includes principal water supply wellfields of NWSC; Bansbhari, Dhobi Khola, Gorkarna, Manohara and the Bhaktapur (West to East). It extends from Katunje in the East to Lamabazar in the West and Budanilkantha in the North to Pashupati in the South.

The deposits are composed of unconsolidated highly permeable materials of micaceous sand and gravel. The unconsolidated coarse sediments are as thick as 60 m, however several impermeable fine layers are interbed with these coarse sediments. This coarse sediment is the main aquifer of the valley. The quality of the groundwater is characterized by low electrical conductivity such as 100 to 200 micro-simens/cm and Transmissivity of the aquifer ranges from 83 to 1963 m2/day. Few wells in this area had artesian outflow at their time of construction.

b) Central Groundwater District

The central groundwater district consists of impermeable very thick black Kalimati clay accompanied by some lignite and peat with a maximum depth of 200m. Unconsolidated coarse sediments of low permeability underlie this thick black clay.

The quality of groundwater is characterized by high electrical conductivity, 1000micro-simens/cm in some wells near Tripureshwor. According to dating analysis of gas well water is about 28,000 years. This means that the groundwater of the central area is probably non-rechargeable stagnant fossil groundwater. The transmissivity of the aquifer ranges from 32 to 960 m^2/day (JICA, 1990). The existence of methane gas in this zone indicates that the groundwater in the deep aquifer is more or less stagnant, and is probably recharged by lateral inflow only (BGR/DMG, 1998).

c) Southern Groundwater District

This area is characterized by a basal gravel of low transmissivity covered by a thick impermeable clay formation. The aquifer is not well developed and is recognized along the Bagmati River between Chobhar and Pharping.

Most of the NWSC wells are located in the Northern ground water district as this area has the best aquifer conditions. Most of the private wells are located in central part of the valley where water contain high quantity of ammonia and nitrogen and are mainly used only for sanitary purposes (JICA, 1990).

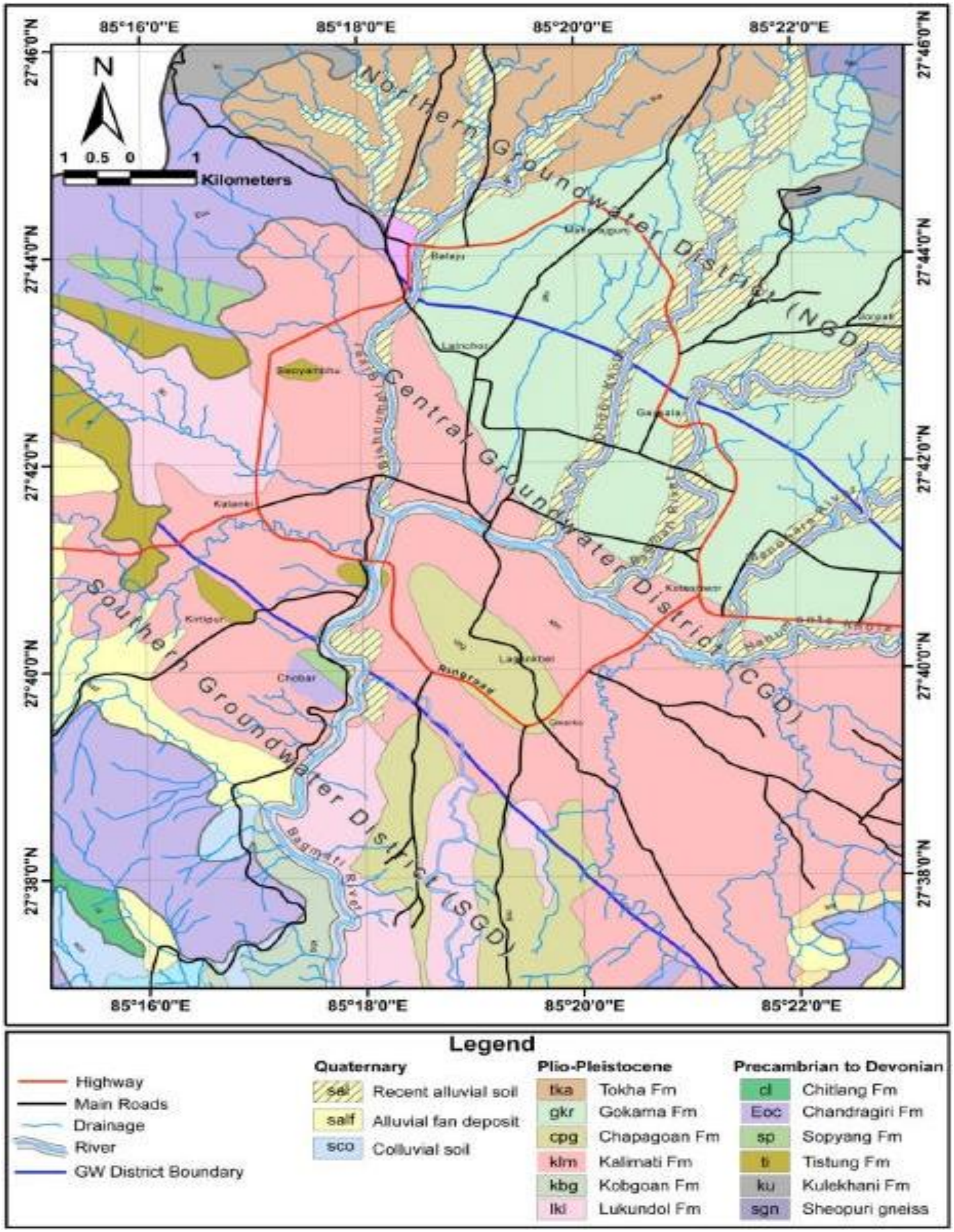

Fig. 2.3.: <u>HYDRO-</u> **Geological District map of Kathmandu Valley (Source: JICA, 1990)**

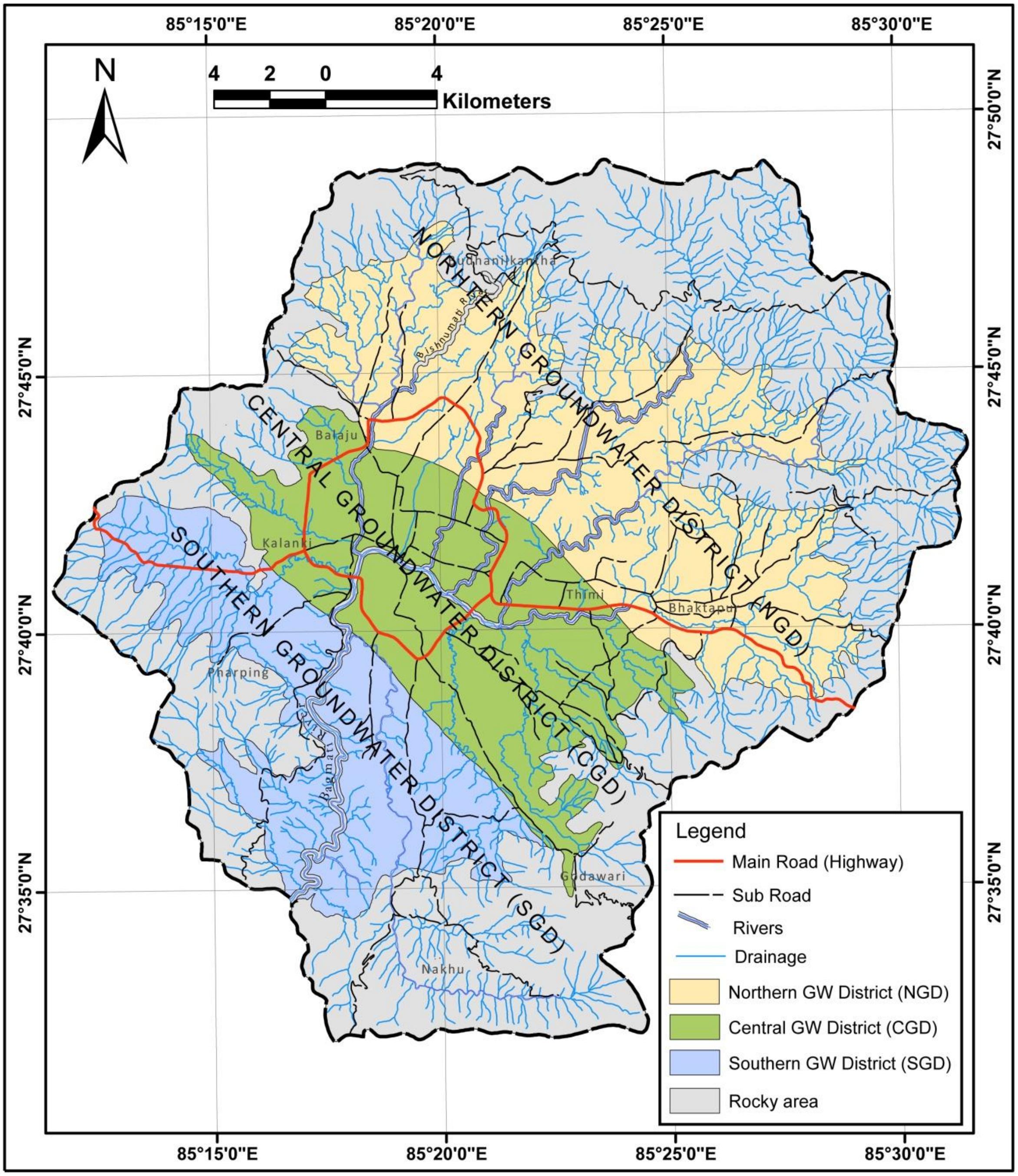

Fig. 2.4.: Hydrological District map of the Kathmandu Valley (Source: JICA, 1990)

2.7. REVIEW OF PREVIOUS STUDIES

Kathmandu Valley is the large oval-shaped International basin stretching 30 Km in East-West and 25 Km in North- South direction with an area of about 650 $Km^{2.}$ The hydrogeology of the Kathmandu Basin has studied by various workers in various aspects. Several published as well as unpublished literatures are found regarding their valuable works. The details of previous work are as follows.

Reviews of Geological Works of Kathmandu Valley

Nautiyal and Sharma (1961) surveyed the hydrogeological condition of the Kathmandu Valley, the type and origin of the sediments and classified the sediments into four members — basal Boulder Beds, clay with minor sand and sporadic gravel beds, carbonaceous clay with diatomaceous Kalimati clay or black soil, and recent alluvial coarse sand and sandy clay with mountain wash and talus in the peripheries of the valley.

Thapa (1977) recognized different lithofacies within the fluvio-lacusterine sediments of the Kathmandu valley. *Facies 1:* Represents the fluvial sediments, well developed in the half of the valley, composing gravels, sand, silts and clay. *Facies 2:* Comprises Lake Delta sediments, developed around the central part of the basin, mainly consisting laminated clay and silt beds. *Facies 3*: Represents proper lake deposits, weakly distributed in the southern half of the basin. It consists of weakly to semi-consolidated mud beds and partly of thin beds of fine sand and diatomaceous earth.

Yamanaka (1982) divided the fluvio-lacustrine sediments of the Kathmandu valley into: Pyanggaon Terraces, Chapagaon Terraces, Boregaon Terraces, Gokarna Formation, Upper Thimi Formation, Thimi Formation, Upper Patan Formation, Patan Formation, Lower Terraces and recent Flood Plain.

Yoshida and Igarasjhi (1984) studied the lacustrine as well as fluvial deposits of the Kathmandu valley. The fluvio-lacustrine sediments of the Kathmandu valley consist of pear, clay, carbonaceous clay (Kalimati), sand and gravel. They have divided these sediments into eight stratigraphic units as follows: Lukundol Formation, Pyanggaon Terraces Deposit, Chapagaon Terraces Deposit, Boregaon Terraces Deposit, Gokarna Formation, Thimi Formation, Patan Formation and Lower Terraces Deposit in the ascending order.

Dongol (1985) subdivided Lukundol formation into four members as Basal conglomerate member, Lignite member, laminated silt member and upper gravel member.

Bajracharya (1992) described the fluvial system of Kathmandu valley in relation to Neo-tectonics and also stated that the origin of Valley Lake is due to accumulation of pent-up water of south flowing rivers.

Sah et. al. (1997) classified the lithological succession of the Kathmandu valley sediments into seven basic lithostratigraphic units, considering the lithological composition, grain size, sedimentary structures and thickness of individual beds. They could be named as Tarebhir Conglomerate, Lukundol Formation, Sunakothi Formation, Shankhu Formation, Gokarna Formation, Thimi Formation and Kalimati Formation.

DMG (1998) prepared Engineering and Environmental geological map of the valley, and divided fluvio-lacustrine deposits of the valley into seven formations as: Basal boulder bed, Lukundol Formation, Kobgaon Formation, Kalimati Formation, Chapagaon Formation, Gokarna formation and Tokha Formation. According to Sharma et, al (1998) and Engineering and environmental Geological Map of Kathmandu Valley published by DMG (1998), the soft fluvio-lacustrine sediments of the Kathmandu Valley is also divided into two series of sediments namely Quaternary Unconsolidated Sediment and Plio-Pleistocene Slightly Consolidated Sediment.

Sakai (2001), divided the Kathmandu basin sediments into Tarebhir formation, Lukundol formation and Itaiti formation in the Southern part, and into Bagamati formation, Kalimati formation with basal lignite member and Patan formation in the central part of the Kathmandu valley.

Reviews of Hydro-geological works

O'Rourke (1955) was the first to study the groundwater condition in the Kathmandu valley and discussed the possible permeabilities of the different sediments in the Kathmandu valley.

Nautiyal and Sharma (1961) were one of the pioneers, who conducted hydrogeological study of the Kathmandu Valley under the Indian Aid Program undertaken by the Geological Survey Indian and Nepal Bureau of Mines. It included a surface geological appraisal, a program of exploratory drilling, measurement of water level movement in shallow wells, observation of some springs and stream flow, and an initial water balance assessment. from the study, they concluded that the groundwater resources of the valley are limited, the aquifer invariably contains clayey material filling the voids or pore spaces there by reducing the porosity and permeability considerably; and the aquifer below the black clay is under flowing artesian conditions and the probably a larger yield could be expected in wells that might pierce the gravels and sands in old river channels.

Sharma, P.N. and Singh, O.R. (1966), studied the groundwater condition of the Kathmandu Valley, under the groundwater exploration program carried out by HMG and the Geological Survey of India. They conducted a detail hydrogeological investigations followed by drilling and compiled a number of exploratory drilling results from the Kathmandu valley and concluded that the total thickness of the sediments varies in different parts; the water quality of the Kathmandu basin is not good since it is contaminated with marsh gas, hydrogen sulphide and also has high iron and silica contents; and the quantity of water, however, is better in the area further north; the groundwater potential zones are confined to the northern parts of the valley.

Binnie and partners (1973) had performed research project on the topic "Groundwater investigation Kathmandu water supply and sewerage scheme". They classified aquifers in seven types as: Inter-bedded, Linear, Bedrock, Basal gravels, river deposits, gravel fans and surface gravels. According to the research the aquifers of the Northern valley are highly stratified and contain layers of all gradations of sediments from boulders, through mixed sand to silt and impermeable clay. They have calculated Transmissivity value between 92 to $301 m^3$/day/m, from which hydraulic conductivities of 1.4×10^{-2} to 1.7×10^{-3} cm/sec were derived for the valley sediments.

Rourke, J.E.; Sharma, C.K.; Rimal, D.N.; and Khan, R.K. (1985), jointly studied the geology preparing the geological map of the Kathmandu Valley with respect to Groundwater.

Binnie and Partners (1988), made a reappraisal study on "Groundwater resources within the Kathmandu Valley" for water supply on the basis of previous hydrological works and some new additional tube wells.

Gautam, R. and Rao, G.K. (1991), made a study on the evaluation and estimation of the total groundwater resources within the Kathmandu Valley. They have classified the whole Kathmandu valley into four aquifer zones. They are Unconfined Aquifer Zone, Two Aquifer Zones, Confined Aquifer Zone and No Groundwater Zone. The Unconfined Aquifer Zones and Two Aquifer Zone lies in the Northern part of the Valley and between the Bishnumati and Manohara River. The Confined Aquifer Zone lies in the central part of the Valley and No Groundwater Zone lies in the area around Sunakothi and Lubhu where no clay free granular zone were observed up to the drilling depth.

JICA (1990) performed research project on the topic "Groundwater management project in Kathmandu valley". According to the research availability of groundwater recharge in the valley is controlled by widespread distribution of lacustrine deposits interbedding the impermeable black clay which prevents easy access to water. They have divided the valley into three groundwater districts as: Northern groundwater district, Central groundwater district and Southern groundwater district. Northern groundwater district is composed of permeable sediments while central and southern groundwater district has low permeability.

Department of Mines and Geology (DMG), Federal Institute for Geosciences and Natural Resources (BGR), Department of Irrigation (DOI), and Geonova (GMBH) **(1998)**, jointly studied the hydrological conditions and potential barrier sediments in the Kathmandu Valley.

S.B. Maharjan (2008) studied on Potential of Groundwater Recharge Through Rainwater Harvesting in the Kathmandu Valley.

Sanjita Mishra (2010) studied on the volumetric augmentation in shallow groundwater due to Recharge from rainwater, effect of rainwater in the quality of shallow groundwater aquifer, and identify potential of rainwater harvesting for managing water within the High Rise Apartments and Housing complexes for sustained water manage.

CHAPTER THREE

METHODOLOGY

The methodologies of study are as follows:

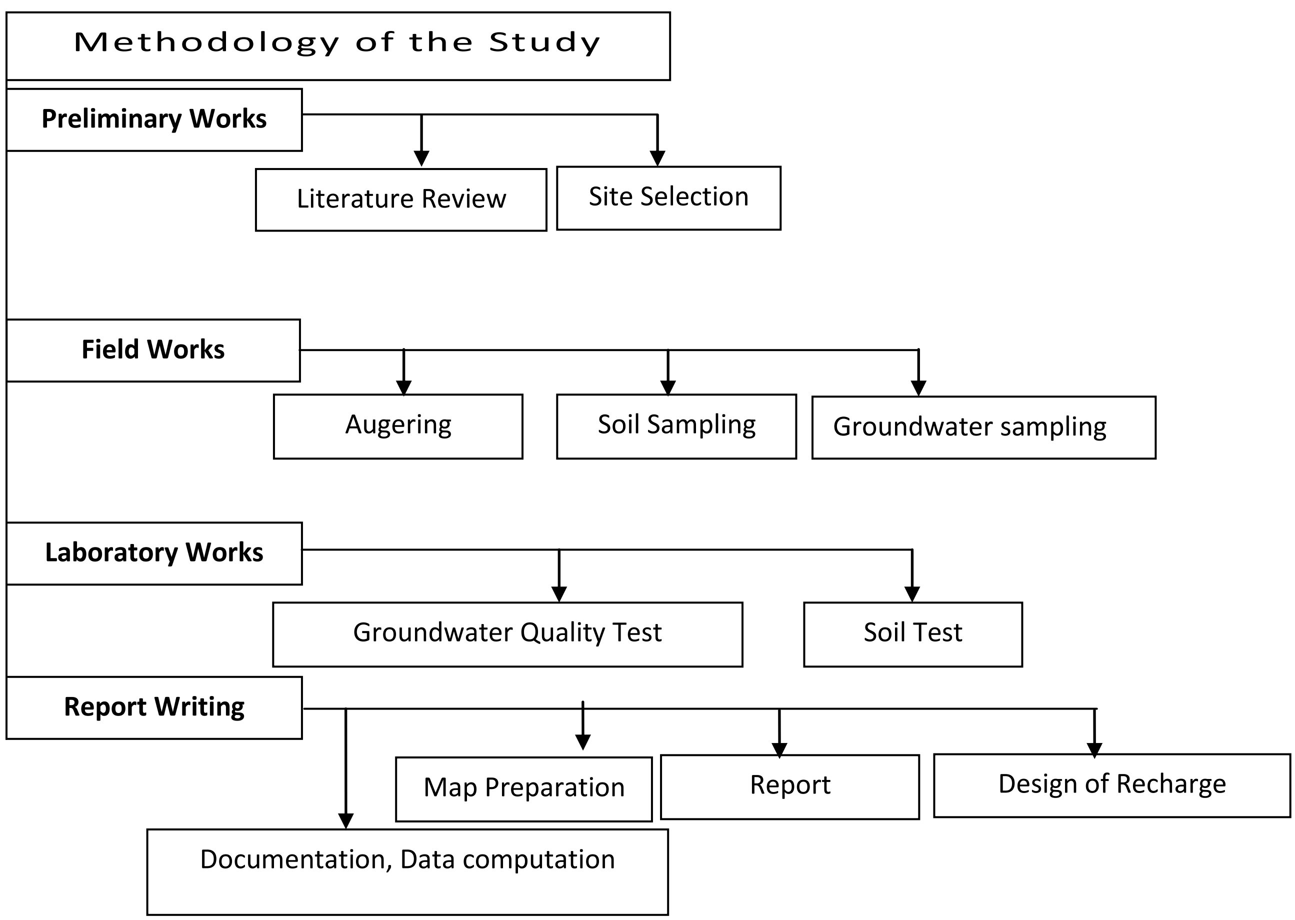

Fig 3.1: Flow chart showing methodology applied during the study.

Methodology includes four stages which are described as below:

3.1. Preliminary Works

3.1.1. Literature Reviews

Documents like geological articles, maps, plans of artificial recharge and other related documents were collected and studied from various sources to the problem and understand the nature of the problem for designing effective study method. The most relevant documents are summarized below and list is given in previous works: (Table.3.1)

Table 3.1: List of the collected reports and their sources

Title	Organization/Author	Year	Source
Engineering and Environmental geological map of Kathmandu.	DMG, Shrestha et al	1998	Report
Hydrogeological conditions and potential/barrier sediments in Kathmandu valley.	BGR /DMG	1998	Report
Groundwater management project in Kathmandu valley	JICA	1990	JICA Report

3.1.2. Site Selection

Selection of sites suitable to meet the objectives of the study is critical for the success of the study. Site selection is dependent upon several factors including local hydro-geology, topography. Number of wells, locations as well as installed recharge pits for sample observations was identified; estimated the catchments area under influence of rainfall within the reach of identified wells and pits. In this context, following factors were considered for the selection of sites:

a) Spatial distribution:

Sampling locations were selected which include most of the areas which can hold maximum potential for rainwater recharge and considering the water scarce situation of the area. The areas where ground water level has dropped considerably were selected / identified for this study as de-saturated aquifer conditions which indicate high potential for recharge. Besides, these areas are also facing acute shortage of water due to unreliability of city supply and heavily dependent on the traditional water sources like traditional dug wells, stone spouts and spring sources which are again drying up due to numerous reasons.

b) Geology and geomorphology:

Sites were located in different geological formations in core areas of Patan having predominance of Kalimati and Chapagoan Formation and geomorphologic conditions so as to observe the effect of sediment type and locations on the recharge potential. Similarly the study sites were located on terraces, slopes and low lying areas to find the most effective locations for groundwater recharge. Different previous studies indicated that Patan area is a potential for recharging hydro geologically as the area prevails with large numbers of dug wells for monitoring water level, installing RWH and recharging system (Figure 3.8: Augering Location Map)

c) Consent of the owners:

For the successful and smooth collection of data and implementation of the study, it is very important to have consent of the owners or the community of the study area. Therefore, the areas were also selected for augering, particularly identification of wells and areas for installing recharge pits were made based on the willingness of community people to cooperate for undertaking the study and to initiate rain water harvesting for recharging groundwater.

3.2. Field Works

Field works includes augering, soil sampling and groundwater sampling. These are given below.

3.2.1. Augering

An *auger* is a drilling device, or drill bit, that usually includes a rotating helical screw blade called a "flighting" to act as a screw conveyor to remove the drilled out material. The rotation of the blade causes the material to move out of the hole being drilled. Augering is the use of drill-like tools to take small samples or columns of sub-surface deposits. These are also known as 'cores' or 'boreholes'.

The advantage of hand augering is that it is fairly quick and easy to carry out, in comparison to more extensive excavation. It can be used to test the depth of deposits, or to retrieve material for further analysis. A hand auger is a narrow cylindrical metal instrument used for drilling down into the ground. At the top is the handle (most often a T-bar which can be twisted to achieve better downward thrust). The shaft is made up of regular lengths (usually 1 meter), which can be extended to as many sections as are available (over 10 meters, the structural stability of the auger may become progressively weaker as more sections are added).

Augering were done upto 137 places of ward no.1 to ward no.22 which lies within the boundary of Ring road and inside the Bagmati River with the interest and consent of the owners and also geomorphological and geological point of view. Different datas of augering were collected from various places of Lalitpur Sub- Metropolitan City of Lalitpur District.(Fig.3.4)

Fig. 3.2: Instruments used in Augering

Fig. 3.3: Performing Hand Augering at Ekantakuna, infront of Sajha Yatayat Bhawan

3.2.2. Soil Sampling

The infiltration rate of the site depend on the soil characteristics such as moisture content, presence of organic matter, soil types etc. Soil samples were collected from the site of augering point.

3.2.3. Groundwater Sampling

Groundwater sample was collected from the different wells from which the recharge to the aquifer through rainwater was conducted. Sterilized bottles were used for sample collection and all the samples were taken to the laboratory (DMG, Babermahal, Kathmandu.) within 4 hours. Sample was collected from 23 wells nearby the augering point area where there is feasibility of high rainwater harvesting zone.

3.2.3.1. Water Level Monitoring in Wells:

Altogether 23 wells were selected in Patan area for the study. The sites were selected with the interest and consent of the owners and also geomorphological and geological point of view. Out of those 23 wells, 23 wells were used for direct sampling and 18 wells were used as monitoring wells on the basis of high feasibility rate of rainwater recharging zone as well as more area contained for recharging into the wells.

Fig. 3.5: Water Level Monitoring in Wells at United Academy, Kumaripati

3.2.3.2. Recharge Potential Zone

The recharge potential zones of the study area were categorized into High (H), Moderate (M) and Low (L) based on the following basis: i.e., a) Infiltration Rate, b) Geology and c) Geomorphology.

Infiltration Rate: The infiltration rates observed from the wells and pits (within the study area as well as outside the study but nearby it) were tested and analyzed during the study. The wells and pits and their locations based on their infiltration rates were categorized into 3 potential recharge areas i.e. High (H), Moderate (M) and Low (L).

Geomorphology: As the recharge is mostly taken place during the monsoon seasons and the ground water level during the monsoon is higher (near the surface) in the Low land area so the low land area is considered as low recharge potential zone whereas the high land (terraces) is considered as high recharge potential area. Points located on terraces have relatively higher infiltration rates than those located on low lands due to high water level in lowlands which rejects rainwater recharge. (Maharjan, S.B.; 2008).

3.3. Laboratory Works

The collected water samples were tested in the Department of Hydrogeology lab, (DMG) Anamnagar, Kathmandu. And the soil samples were tested in the Lab. of Central Department of Geology, Tribhuvan University, Kirtipur. During the soil test, the grain size of the sediment was analyzed by mechanical sieving.

3.3.1. Groundwater Quality Analysis

The analysis of water quality data is done by comparing with standards guidelines values for drinking water and seasonal variation of constituents in each individual well.

3.3.1.1. Water Quality Test

The water sample was tested by the following parameters. They are as follows:

AMMONIA (NH3) TEST

Procedure

For Undistilled samples-

1. 1ml. $ZnSO_4$m solution was added to 25 ml. samples and mixed thoroughly.
2. 0.4-0.5 ml. 6N NaOH solution was added to obtain a pH of 10.5 as determine with a pH meter, and then mixed again thoroughly.
3. The treated sample was allowed to stand for a few minutes whereupon a heavy flocculent precipitate had fallen with a clear and colorless supernatant liquid.
4. Then the sample was filtered such that the first 5 ml. filtrate was discarded and then 1 drop of EDTA reagent and 2 ml nessler was added.
5. A blank and standard of 1,2,3,4 ml. diluting to 5 ml with ammonia free water was prepared.
6. The blank and standard was nesslerized by adding 1ml. nessler reagent to each and was well mixed.
7. Then, the absorbance was measured in a spectrophotometer of blank as a standard and then test sample.

pH TEST

Procedure-

1. The instrument was standardized with the buffer solutions after an appropriate warm period (in that condition, samples and buffers must be at the same temperature).
2. Then the pH of the samples was measured.

EC TEST

Procedure-

1. The instrument was standardized with the buffer solutions after an appropriate warm period (in that condition, samples and buffers must be at the same temperature).
2. Then the EC of the samples were measured.

TEMPERATURE

Procedure-

1. The instrument was standardized with the buffer solutions after an appropriate warm period (in that condition, samples and buffers must be at the same temperature).
2. Then the temperature of the samples was measured.

CALCIUM (Ca) TEST

Procedure-

1. A volume of sample containing less than 5 mg of calcium i.e.25 ml into a 100 ml beaker was pipetted.
2. The beaker was inserted in the titration assembly and stirrer was started.
3. Then after 1ml $NH_2OH.HCL$, 1ml am NaOH was added and also 1ml NaCN solution was added (if the sample does not contain heavy metal, addition of NACN is omitted).
4. 0.2gm murexide indicator was also added and proceeded immediately with the titration.
5. Titration was done with Na_2EDTA standard solution until purple swirls begin to show.(The end point is reached when the sample color change from salmon to orchid purple)
6. Water, the normal; blank correction which is 0.05 or 0.10 ml was determined.

CHLORIDE (Cl) TEST

Procedure-

1. 25 ml of sample was pipette into a beaker and the volume was adjusted to approx. 25ml.
2. Then 2 drops of K_2CrO_4 indicator solution was added and titration was done with silver standard solution with constant stirring until the pink-red (yolk color) $AgCrO_4$ persists for 10 to 15 sec.
3. After that a blank correction was determined by similarly titrating 25 ml distilled water.

COLIFORM TEST

Procedure-

1. Samples for microbiological examination were collected and were held in cleaned containers and were sterilized by autoclaving at 121^0c at 1.05 kg/cm^2 (15 psi) for at least 15 minutes.
2. Caps or stoppers were loosed during autoclaving to allow the steam to contact all surface.
3. When the sample is collected, sample air space was left in the container to facility mixing of the sample by shaking and then bottle closured was water tightly filled.
4. Size of the sample was governed by the expected bacterial density of water being tasted.
5. An ideal quantity was resulted in the growth of about 20 to 80 total coli form coli form colonies and not more than 200 colonies of all types.
6. A sterile absorbent pad was placed in the bottom of each sterile plastic Petri dish flame-sterilized forceps.
7. Forceps was dipped in ethyl or methyl alcohol and was passed through frame to ignite alcohol then allowed to burnout.
8. About 2 ml Endo preservative medium was added in flame saturated of each pad and the Petri dish was tilted to excel excess liquid then Petri dish tops was replaced without making tight.
9. The funnel and filter base of the assembly separately was wrapped in Kraft paper or polypropylene bags and also sterilized in the autoclave at 121^0c at 1.05 kg/cm^2(15 psi) for 15 minutes. Then cooled to room temperature before it was used again.
10. The filter holder was assembled and a sterile membrane filter was placed over the porous plate of the assembly by using flame-sterilized forceps.
11. Then funnel was placed carefully on filter to avoid tearing or creasing the membrane. After that the sample was shaked vigorously about 25 times to obtain an equal distribution of bacteria thought the sample before transferring a measured portion of the sample to the filter holder assembly.
12. The sample was applied and filtered. And also rinsed sides of funnel twice with 20 to 30 ml of sterile buffered distribution water while applying vacuum.
13. The funnel was removed from the base of the filter-holder assembly by maintaining vacuum and also removed the membrane filters from the base by using flame sterilized.
14. Then the membrane filters were placed on the broth soaked absorbent pad in the plastic Petri dish, grid side up by using a rolling action at one edge.
15. Top was placed on Petri dish and also proceeded with filtration of next volume of water.
16. The lid of each Plastic Petri dish was clearly marked indicating location, time of collection, time of incubation, sample number, and sample volume with the help of water proof felt-tip marker or grease pencil.

17. The plastic dish was closed by firmly pressing won on the top.
18. The filters were incubated in the tightly closed Petri dishes in an inverted position at 35^0 +or - 0.5^0c for 20 to 22 hours.
19. Incubation was done for filters within 20 minutes after placement on medium using forceps, removed the filters and dried for at least 1 minute on an absorbent surface. Membrane that has colonies having poor sheen production was allowed to dry completely which will enhance the production.
20. Counting was done with the help of acid of low power (10-15 magnification) binocular wide-field dissecting microscope.
21. All cultures were autoclaved at 121^0c at 1.05 kg/cm^2 (15 psi) for 15 minutes before discarding.

IRON (Fe) TEST

Procedure-

1. Filtered Samples were filled and acidified with reagent grade HNO_3 and stored in a tightly capped polyethylene bottle.
2. A 25 ml sample was pipette into a 50 ml beaker and the volume 5 to 25 ml was adjusted with distilled water.
3. A blank of distilled water was prepared and also prepared standards of 5, 10,15,20,25 ml etc.
4. Then the volume to 25 ml was adjusted. Again 1 ml bipyridine solutions were added and 2 ml hydroxylamine hydrochloride solution was added and then mixed in order to allow standing 30 minutes.
5. Again 2 ml $NaC_2H_3O_2$ solution was added and mixed.
6. The absorbencies of the sample, blank and standard were determined.

NITRATE (NO3) TEST

Procedure-

1. A volume of sample, blank and sufficient standards was pipetted in a 25 ml beaker and the volume of each was adjusted to 5 ml.
2. 2 ml NaCl solution was added and mixed well by swirling and then the beaker was placed into cold water bath (15-20^0c) and again 10 ml of 29 N H_2SO_4 was added .
3. After that the sample was mixed well by swirling, returned to cold water bath and the contents of the beaker were allowed to cool to water-bath temperature.
4. 0.5 ml brucine-sulfanilic acid solution was added and mixed thoroughly.

5. The beaker was discarded from the cold-water bath and placed in a boiling water bath for 20 minutes. Again cooled in a cold-water bath.
6. Then the absorbencies of the sample and standards were determined against the blank without delay.

SULPHATE (SO_4) TEST

Procedure-

1. A blank of distilled water and standards of 5, 10, 15,20,25,50 and 100 ml sulphate standard solution IV were prepared and the volume was adjusted to 25 ml using distilled water.
2. Again 5 ml reagent solution was added in each samples and mixed well.
3. The absorbencies of the blank and standards were added at 340 nm.
4. A sample of 25 ml maximum was pipette into a 100 ml beaker and the volume was adjusted to 25 ml with distilled water.
5. 5 ml reagents solution was added and mixed well.
6. Then at last the absorbency of the sample was determined.

TOTAL HARDNESS TEST

Procedure-

1. A volume of sampling containing less than 25 ml hardness was pipetted into a 100 ml beaker, and also the volume to approx. 25 ml was adjusted.
2. The beaker was inserted in the titration assembly and the stirrer was started. Then 1 ml $NH_2OH.HCl$ solution, 1 ml conc. NH_4OH was added. At last 2 ml NaCN solution was added.
3. One or two small crystals potassium ferrocyanide was added in case of presence of Mn.
4. The solution was stired and left least 5 min. until the $Mn_2Fe(CN)_6$ was precipitates. After that 2 ml eriochrome black T indicator solution was added.
5. Titration was done with Na_2 EDTA standard solution until blue or purple swirls begin to slow.
6. The end point was reached when all traces of red and purple have disappeared and the solution was seen clear blue.
7. The change color occurred rapidly.

MAGNESIUM (Mg)

Procedure-

1. After obtaining value of Total Hardness and Calcium, value of Magnesium was obtained from calculation.

i.e., Mg in me/l= Hardness in me/l – Ca in me/l

Mg in mg/l= (Hardness in me/l – Ca in me/l)* 12.16

PHOSPHATE (PO_4) TEST

Procedure-

1. A volume of 25ml sample was pipetted into a 100 ml beaker into a 100 ml beaker and the volume was adjusted to 25 ml.
2. A blank and sufficient standard were prepared and the volume of each were adjusted to 25 ml.
3. Then 5 ml combined reagents solution was added to each sample i.e, blank and standard and then were mixed.
4. After 10 to 30 minutes. Absorbencies of each sample and standard were measured against blank at 800 nm.

CARBONATE (CO_3) TEST

Procedure-

1. From a settled, unfiltered sample, a volume containing less than 40 ml alkalinity as HCO_3-1, i.e., 25 ml was pipetted into a suitable beaker.
2. The beaker was inserted in titration assembly and pH value was recorded.
3. Again titration was done immediately with 0.1639 N sulfuric acid and then the titration volume was recorded at pH 4.5.

Fig. 3.6: Water Quality Analysis Testing at Babarmahal, Kathmandu

3.3.2. Soil Test

The collected Soil samples were tested in the Lab. of Central Department of Geology, Tribhuvan University, Kirtipur. During the soil test, the grain size of the sediment was analyzed by mechanical sieving. First the soil sample was dried in the oven at 50^0 C and then the dried soil sample was slightly hammered just to disintegrate particles. At last, sieve analysis process was done.

3.3.2.1. Sieve Analysis

A sieve analysis is a practice or procedure used to assess the particle size distribution (also called gradation) of a granular material. The size distribution is often of critical importance to the way the material performs in use. A sieve analysis can be performed on any type of non-organic or organic granular materials including sands, crushed rock, clays, granite, feldspars, coal and soil, a wide range of manufactured powders, grain and seeds, down to a minimum size depending on the exact method. Being such a simple technique of particle sizing, it is probably the most common analysis.

The percentage of different sizes of soil particles coarser than 75 micron is determined coarse grained soils which are classified mainly by sieve analysis. The grain size distribution curve gives an idea regarding the gradation of the soil i.e., it is possible to identify whether soil is well or poorly graded.

Sieve Analysis Procedure

A sample of dry soil is poured onto the top sieve, the nest is covered, and it is then shaken b**y hand** or **mechanical sieve shaker** until each particle has dropped to a sieve with openings too small to pass, and the particle is retained. The cumulative weight of all material larger than each sieve size is determined and divided by the total sample weight to obtain the percent retained for that sieve size, and this value is subtracted from 100% to obtain the percent passing that sieve size.

Results are displayed by plotting the percent passing (on a linear scale) against the sieve opening size (on a log scale) and connecting the plotted points with a smooth curve referred to as a grain-size distribution curve.

Fig.3.7: A Complete Instrument of Sieve Analysis

3.4. Report Writing

After completion of field work, the data collected were further studied and analyzed to evaluate hydrogeology and it's condition of the study area and generalized as in followings:

Final preparation of the Geological map, Drainage map and Location map of well sites as well as augering points were prepared by ArcGis software with the reference to the geological map of the Kathmandu Valley (shrestha et al.1998). And also Water table maps, litholog cross section were prepared from the collected datas using freehand software V11. At last, the datas and the maps were studied in detail, analysed and final report was made based on the interpretation.

MAPS

Fig.3.4: Augering Point Location of Study Area (Lalitpur Sub-Metropolitan City)

Fig.3.8: Augering Location Map

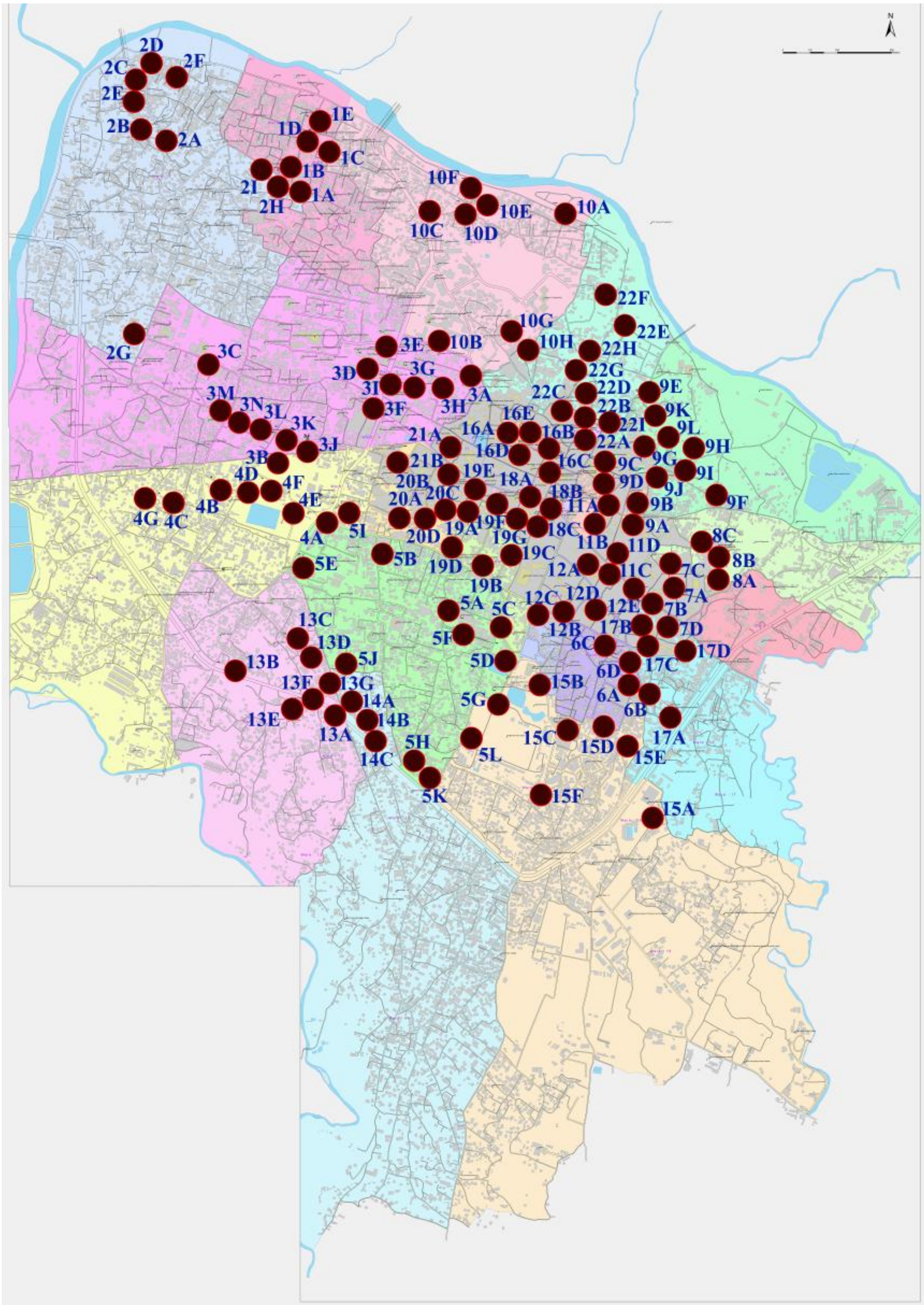

Fig.3.4: Augering Point Location of Study Area (Lalitpur Sub-Metropolitan City)

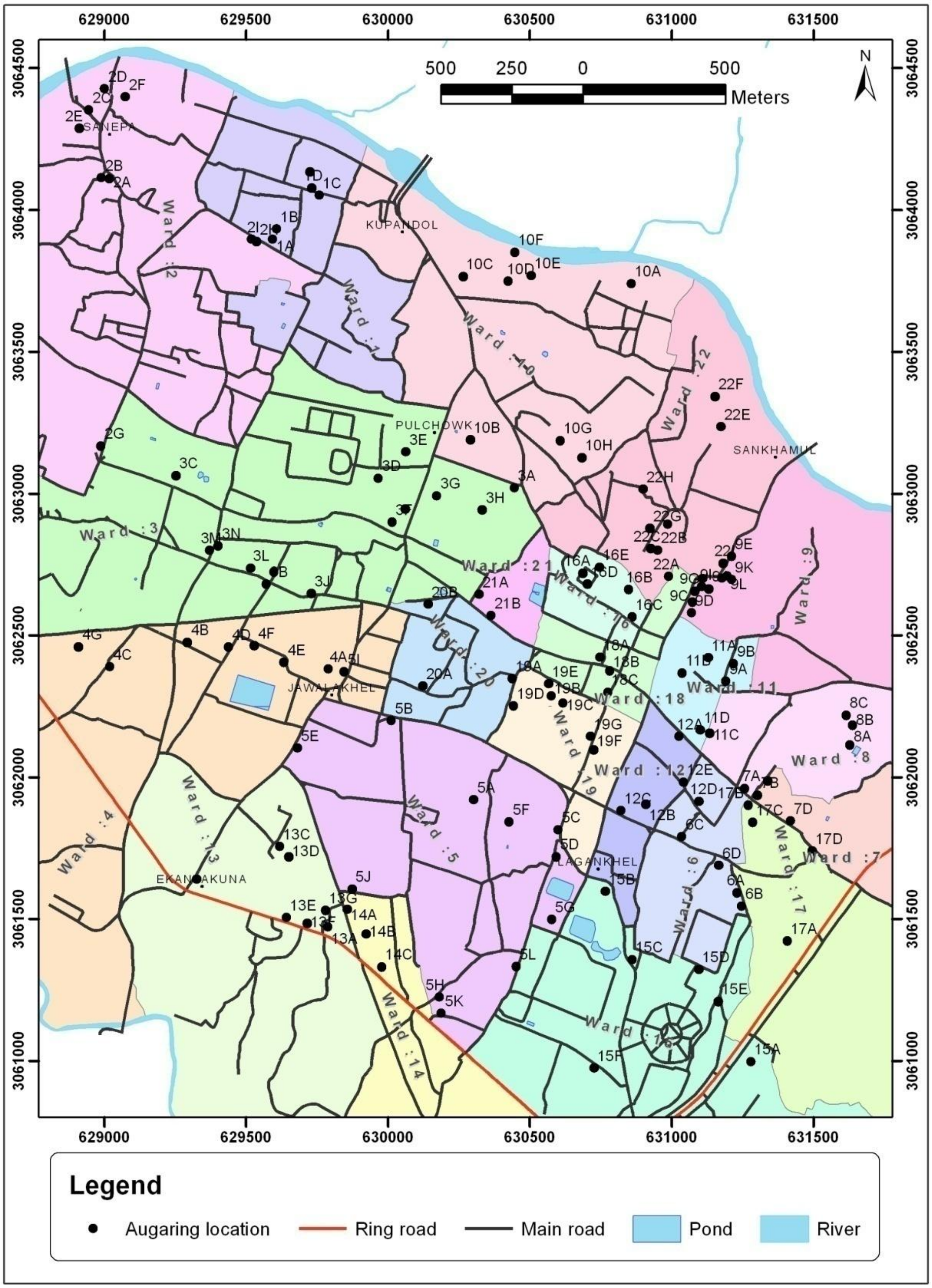

Fig. 3.8: Augering Location Map

CHAPTER FOUR

DATA AQUISITION

Accurate and adequate acquisition of related parameters for the study plays a pivotal role in the study. Such parameters can be attained through the comprehensive field works aimed at collecting site specific data. Apart from providing primary data, field works also help to verify and supplement the secondary data on which preliminary reports are based during literature review.

4.1. Hand Augering

All together 137 augering was done in different places of ward no.1 to ward no.22 of Lalitpur SubMetropolitician City (Table No.4.1, Annex II). The augering places lie within the boundary of Ring road and within the boundary of Bagmati River which was chosen according to geology, geomorphology and consent of the owners. The capacity of augering is upto 17 ft. but according to the geology, geomorphology of the area and gravel found in low depth, some places augered less than 17 ft..It's because the main objective was to find gravel depth for groundwater recharge. Table No.4.1 gives the list of the locations and the lithology at the hole to the depth of 17 ft.

4.2. Mechanical Seive

In total, 137 augering locations were augered. Out of 137 augering, 11 samples were analysed for grain size. Soil samples were analysed by mechanical sieving (Table No. 4.2.1 to table No.4.2.11, Annex IV). The data was analysed through excel and the plotted as shown in (Fig.4.2.1. to 4.2.11, Annex IV) to understand the properties of the soil.

4.3. Groundwater Quality

Quality of groundwater changes as water flow along into the underground environment as a result of water-soil-rocks interactions. The longer the water remains underground and the further it travels, more minerals get dissolved. In the case of shallow wells, anthropogenic influences and leachate from solid waste dumping sites, inappropriate dumping of solid waste, use of agro-chemicals, lack of treatment of urban and industrial liquid waste etc are the main causes of groundwater as well as surface water pollution.

Different parameters of the water quality are matter of concern for different purpose according to uses of ground water. World health organization (WHO) has recommended drinking water guideline value for more than 120 parameters among them relatively important parameter for drinking purpose are discussed here.

The samples were however analysed for following parameters as the purpose was to study the potential of contamination of rainwater recharge and also the impact of rainwater recharge on existing water quality.

- **Turbidity:** Indicates suspended particles in water. WHO guideline for turbidity is 5 NTU.
- **pH:** pH indicates acidic alkaline nature of water. Lower pH cause corrosion in distribution system of water supply and pH above 8 decrease chlorination efficiency. WHO guideline for pH is 6.5 to 8.5.
- **Conductivity:** Conductivity is the measure of capacity of a substance or solution to conduct electrical current. Conductivity is the reciprocal of resistance.
- **Hardness:** Hardness is caused by carbonates and bi- carbonate salts of calcium and magnesium. WHO guideline for hardness is 500 mg/l. According to DUFOR 1964, Degree of hardness in ground water can be expressed in terms of $CaCO_3$ and classified

as soft (0-60 mg/l), moderately hard (60-120 mg/l), hard (121-180 mg/l) and very hard(>181 mg/l).

- **Chloride:** Chlorides corrode metals and effect taste of food. Chloride can contaminate surface water. Aquatic communities can't survive in high level chloride. WHO guideline value for chloride is 250 mg/l.
- **Ammonia:** Ammonia pollution is caused by human activities and natural decay process. WHO guideline for ammonia is 1.5 mg/l.
- **Nitrate:** Source of nitrate in water is the biological oxidation of organic nitrogenous substances. WHO guideline for nitrate is 50 mg/l
- **Iron:** Almost all water contains dissolved iron rottenly only in trace. WHO guideline for iron is 0.3 mg/l.
- **Manganese:** Manganese dissolves into water when it passes through underground layers containing manganese. Rain water is generally manganese free. WHO guideline for manganese is 0.1 mg/l.
- **Arsenic:** Arsenic is a metalloid element present normally in the earth's crust. Prolong consumption of water having abnormally high arsenic cause's adverse effect in human health. WHO guideline for arsenic is 0.010 mg/l. Nepal’s interim standard 0.05 mg/l.
- **Microbiological quality:** Water may content disease causing pathogens. Rainwater is pathogen less. It may contain some air microbes which is not harmful for human health.

CHAPTER FIVE

DATA ANALYSIS AND INTERPRETATION

5.1. Hand Augering

Data obtained from 137 augering locations are given in table no. 4.1(Annex II). Most of the locations in South-West part (ward no.6, 7, 8, 9, 11, 12, 15 and 17) (Table No.5.1 (Annex V), Fig.3.1) contained Kalimati soil (about 90%) with little or no gravel beds(about 10 %). Some places in the North-East (ward no. 1, 2 and 3) as well as North-West (ward no.10, 22, 9, 16, 18, 16, 19 and 20) contained medium to fine sand and the central part (ward no. 4 and 5) of the study area contained gravel. Ward no.1, 8 and 21 contain no aquifer material. So, this area is not good for ground water recharge. Ward no.2, 3, 7, 10, 16, 18, 19 and 22 contained little aquifer materials (0-2 inch thin beds). So, this area is less feasible for groundwater recharge. Ward no. 4, 5, 6, 9, 11, 12, 13, 14, 15, 17 and 20 (Jawalakhel, Lagankhel, Thaina, Kobahal, Kutisaugal, Ha:kha Tole, Kusunti, Thasikhel, Satdobato, Sundhara, Purnachandi etc) contain almost all aquifer material. Since area dominated by coarse sediments have high infiltration rate, this area is best for groundwater recharge and recharge pits can be for more recharge to the ground. This clearly shows that these ward area have large potential for groundwater recharge. Ward no.5 .i.e., Lagankhel area (Patan hospital and Sajha Bhawan's building) is the best area for groundwater recharge as aquifer material is found in low depth i.e., at 0.5 ft. So, it is suitable for potential rainwater recharge.

It is observed that ward no. 5 (Patan Hospital and Sajha Bhawan's Building area) having thick zone of aquifer material about 5-10 ft. Therefore that area is probable recharge area which was identified on the basis of gravel found. Table No. 4.2 shows the location of probable recharge zone and thickness of aquifer which was chosen according to coarse sand as well as gravel found i.e., aquifer zone of the Lalitpur Sub Metropolitan City. (Annex II)

5.2. Mechanical Seiving

The details of seive analysis data is given in Annex V. The final results of sieve analysis of 11 samples are given below in table no.5.1.

Table No. 5.1: Classification of Soil of study area after Seive Analysis

S.No.	Ward No.	Location No.	Location Area	Uniformity Coefficient(CU)	Coefficient of Gradation(CC)	Result	Remarks
1	1	1D	Gusingal	5.13	0.72	SW	
2	2	2F	Gusingal	2.67	0.03	GP	
3	3	3J	Jawalakhel	7.50	1.07	SW	
4	4	4D	Jawalakhel	11.58	2.16	SW	
5	5	5C	Manbhawan	10.0	0.54	SW	
6	5	5I	Jawalakhel	6.67	0.50	SW	
7	10	10E	Jwagal	6.57	1.01	SW	
8	10	10F	Jwagal	8.0	1.12	SW	
9	13	13F	Kumaripati	7.83	1.02	SW	
10	15	15B	Lagankhel	13.33	1.01	SW	
11	22	22I	Shankhamul	7.92	1.07	SW	

Note: SW= Well Graded Sand, GP= Poorly Graded Gravel

From the above table, it is concluded that the study area having mainly well graded sands except ward no. 2 Gushingal area at location point 2F; the value of CU is less than 3 i.e., 2.67 and CC is 0.03.

5.3. Water Quality

The sources and quality of water are major concerning matter at present condition. As we know, most of the study area is densely populated and utilize plenty of groundwater haphazardly. This later changes quality of groundwater as water flow along into the underground environment as a result of water-soil-rocks interactions. So the groundwater most be tested before use as a drinking purpose. The result of the ground water quality tests are listed in table 5.2.1 to 5.2.12. (Annex III)

Table 5.2: WHO standard value of water quality test

S.N.	Type	Value	Remarks
1	pH	6.5-8.5	
2	EC (uS/cm)	1500	
3	Color (TCU)	5(15)	
4	Turbidity (NTU)	5(10)	
5	T. Hardness (mg/l)	500	
6	Chloride (mg/l)	5	
7	Ammonia (mg/l)	1.5	
8	Nitrate (mg/l)	50	
9	Nitrite (mg/l)	3	
10	Iron (mg/l)	0.3(3)	
11	Maganese (mg/l)	0.4	
12	Arsenic (mg/l)	0.01	

Table No.5.3: Summary of Water Test Analysis of Study Area

S.N	Location	Iron	Ammonia	Total coliform	EC	pH	Temp.	Hard ness	Calcium	Magnesium	Chloride	Phospate	Nitrate	Sulphate	Remarks
1	Blank	0	0		51	6.65	146.6	0.00	0.00	0.00	0	0.0	0	0	
2	W1	<0.001	0.07		29	6.71	81.9	3.34	2.87	5.74	1.6	28.6	31.23	37	
3	W2	0.0001	0.03		63	6.96	96.3	2.17	1.32	10.47	3.4	8.0	25.10	29	
4	W3	0.0002	0.08	20	36	6.74	163.2	2.17	1.71	5.72	0.95	28.3	29.98	29	
5	5C w2	0.0002	0.36		54	9.18	91.2	4.58	3.49	13.35	1.6	8.3	<0.01	22	
6	16-Na-ch	0.0001	0.05		64	6.75	146.6	2.48	1.09	17.12	4.4	7.5	36.48	51	
7	16-Nag	<0.001	0.06		40	6.57	119.2	3.72	2.48	15.24	2.75	6.5	34.70	31	
8	20 Gynbd	0.0002	0		27	6.75	145.1	3.88	2.09	21.89	4.35	0.8	2.95	63	
9	9-Taro	0.0002	0.07		43	8.31	93.5	3.57	1.71	22.83	0.95	7.2	1.87	35	
10	9 L tt	0.0017	0.09		50	8.21	125.1	1.32	0.47	10.46	0.5	7.6	4.43	34	
11	19 C	<0.001	0.08	NIL	78	7.91	99.8	3.26	2.17	13.33	1.45	8.6	2.27	48	
12	9B W1	<0.001	0.13	10	52	7.18	36.6	10.7	3.26	91.28	5	0.9	8.14	43	
13	16 Ilanani	<0.001	0.03	TNTC	74	6.25	46.8	3.72	2.56	14.29	3.1	6.6	2.76	32	
14	14A w2	0.001	0.05	NIL	59	6.62	163.3	2.17	2.95	-9.47	2.5	4.9	29.20	52	
15	6B	0.0009	0.06	NIL	62	6.95	83.5	13.5	1.94	141.6	1.05	8.9	26.70	16	
16	W3 UA	0.0003	0.05	NIL	56	6.46	126.5	3.65	1.94	20.93	4.95	4.0	5.09	50	
17	w2 UA	0.0491	0.05		25	6.85	154.2	3.1	1.4	20.93	3.85	10.1	20.23	13	
18	W1 UA	0.0002	0.03	TNTC	61	6.55	73.6	4.73	3.72	12.4	3.65	4.4	4.89	41	
19	5E W1	0.0061	0.23		109	6.52	144.2	2.87	3.72	-10.4	3.2	2.7	25.53	42	
20	14 A w1	0.0011	0.1		47	6.17	76.5	5.66	3.88	21.91	2.85	9.5	8.75	59	
21	5C w1	0.0093	0.05		51	6.82	148.1	3.88	2.33	19.04	4.3	8.5	35.68	37	
22	5E W2	0.0589	0.05		86	9.22	103.6	4.58	2.17	29.49	0.75	8.1	39.33	43	
23	9B W3	0	0.05		72	6.34	117.2	1.86	0.7	14.27	5.4	5.4	3.48	75	
24	14 A W3	0.0011	0.04		51	6.65	146.6	3.57	11.32	-94.9	1.9	8.0	13.45	55	

The data comes from water test of different location of study area is correlated with standard value of WHO. Almost all the values is less than WHO standard value except pH value of location 5EW2 which is 9.22.

5.4. Infiltration Rate

The infiltration tests carried out in the recent past (Maharjan S.B., 2008) shows whether the area is suitable for recharge or not. The datas were performed for three seasonal periods- Pre-monsoon Monsoon and Post-monsoon. The distribution of infiltration test conducted by different structure was listed below. (Table No.5.4)

Table 5.4.: Distribution of Infiltration

Pre-Monsoon						
	Lalitpur	Bhaktapur	Kathmandu	Kirtipur	Thimi	Total
Dug Well	3	0	9	0	0	12
Pit	1	1	2	0	0	4
Tube well	0	0	2	0	0	2
Infiltrometer	9	3	17	2	2	33
Total	13	4	30	2	2	51
Monsoon						
Dug Well	3	0	8	0	0	11
Pit	1	1	2	0	0	4
Tube well	0	0	2	0	0	2
Infiltrometer	9	3	17	2	2	33
Total	13	4	29	2	2	50
Post-Monsoon						
Dug Well	2	0	7	0	0	9
Pit	1	1	2	0	0	4
Tube well	0	0	2	0	0	2
Infiltrometer	9	3	17	2	2	33
Total	12	4	28	2	2	48

The rate of infiltration and discharge rate were calculated by using following formulas;

Infiltration rate = water level difference/ measured time interval.

The infiltration rate from the different sites was classified into 3 phases as high, moderate and low.

High Infiltration Rate: Infiltration rate higher than 0.6cm/min is categorized as high infiltration rate.

Moderate Infiltration Rate: Infiltration rate lies between 0.06cm/min to 0.6cm/min are categorized as moderate infiltration rate.

Low Infiltration Rate: Infiltration rate 0.06 cm/min or lower are categorized as low infiltration rate.

The results of infiltration rate from above Table No.5.4 show strong influence of geology or geomorphology or both on the infiltration data and their variation of Infiltration data from pre-monsoon, monsoon and post monsoon is 13, 13 and 12 respectively. Most of high and moderate to high infiltration points are located on terraces or slopes. The sites are located on the terraces with water table at depth and de-saturated, relatively coarse grained aquifer material of higher permeability lying between the water table and the surface.

All points are located Locations having moderate and low to moderate infiltration rate 13 to 12. Most of the sites have lowest infiltration which is typical of fine grained sediment like clay and silt which have comparatively lower permeability and do not allow smooth flow of water between the sediment grains. Also most of these sites are located on low lying area which normally has near surface water level and reject rain water recharge. The water level of different wells is different .The water level ranges from 2 m to 10 m.

Discussion: Geologically, the study area is located in two formations- Kalimati Formation and Chapagaon Formation. For the zoning, sites located in the Chapagoan Formation composed of coarse sediments (Gravels and sands) which have high permeability is considered as high recharge zone and sites located in the Kalimati Formation composed of fine sediment (clay, silt and sands) having low permeability is considered as low recharge zone. The present study has shown that areas around

Jawalakhel, Gabahal, Kumaripati and Lagankhel in Lalitpur Sub Metropolitan City show immense potential for rainwater recharge due to the geological stratigraphical condition and geomorphologic conditions (due to presence of coarse grained depoits at shallow depth which is suitable for recharge area). As this area consists of Chapagaon Formation of sediments consisting of sand and gravel which are highly permeable, any recharges from these places are likely to flow down slope to north or south. However residents from these areas are unlikely to benefit directly from the recharge. On the other hand residents in the core part of Lalitpur Sub Metropolitan City area from Pulchowk, Gabahal, Patan Durbar Square area and Sundhara as the people are facing water scarcity due to decreasing water level in the wells, may be able to benefit from the recharge in the south. This however would be possible only if the recharge is done in massive scale. These areas have infiltration rate 0.08 cm/min., 0.1cm/min. and 0.4cm/min. which results high to moderate infiltration potential. However as most of the above locations also lie on terraces, they show moderate to high recharge potential but Lagankhel (Sajha Bhawan) areas provide 0.09 cm/min. which results moderate recharge potential. Most of the flood plains and other low lying areas especially in the ward 4 and 5 provide 0.05 cm/min. which results low infiltration rates primarily due to fine sediments and higher water table.

Dug well would be more feasible in common places like bahals and chowks rather than private residential buildings for groundwater recharge. On the other hand small pits would be more feasible in private residential buildings since gravel depth found at low depth i.e., at 2.8 ft. in Jawalakhel ward no. 3B, at 2.0.9 ft. in Dhobichaur,Thado Dhunga ward no. 3H, at 2.3 ft. in Un Habitat Office ward no. 3I, at 3 ft. in Jawalakhel ward no. 3J, at 2 ft. in Jawalakhel ward no.3L, at 1.5 ft. in Jawalakhel ward no. 4B, at 1.5 ft. in Manbhawan ward no. 5B, at 1 ft. in Jawalakhel ward no.5I, at 1.5 ft.in Ekantakuna ward no.13B, at 2 ft. in Ekantakuna ward no.13D, at 2 ft. in Kusunti ward no. 13G, at 2.5 ft. in Thasikhel ward no. 14B and at 2.5 ft.in Kusunti ward no.14C(Annex VI) Most newly constructed buildings have no provision to collect or recharge rainwater. All the rain that falls on the roof or the compound is drained away through the sewer pipe. Minor modification in the existing plumbing is adequate to collect and or recharge rainwater into groundwater. The size of the pit to be dug for recharge depends on factors like the size of the catchments, intensity of rainfall, rate of recharge, which depends on the geology and geomorphology of the site.

Also from the lithologs of the selected augering points, the central core area of Patan-around Lagankhel, Jawalakhel Kupondol, Sanepa, Pulchowk, Satdobato and Banglamukhi area are feasible for recharge because the percentage of coarse material is higher than fine (about 60%) and there is more open space and more agriculture land as well as the top surface of the area is composed of sandy gravel of Chapagaon Formation in which fine grained sand started at the depth of 1.5 ft. and at 3.5 ft. gravel found as well as gravel found at 0.5 ft. also in the periphery of Patan Hospital area. (Shown in lithologs of Patan Hospital. (Annex I))

From the above data analysis show that the percentage of coarse material is 90% at Lagankhel area especially Patan Hospital periphery and infiltration rate is 1.2 cm/min which is relatively higher than other study area. It is concluded that Lagankhel area is more feasible than others.

MAPS

Fig.5.1: Geological map of aquifer zone and augering Location

Fig. 5.2: Different geological and Lithological contact and Augering Location

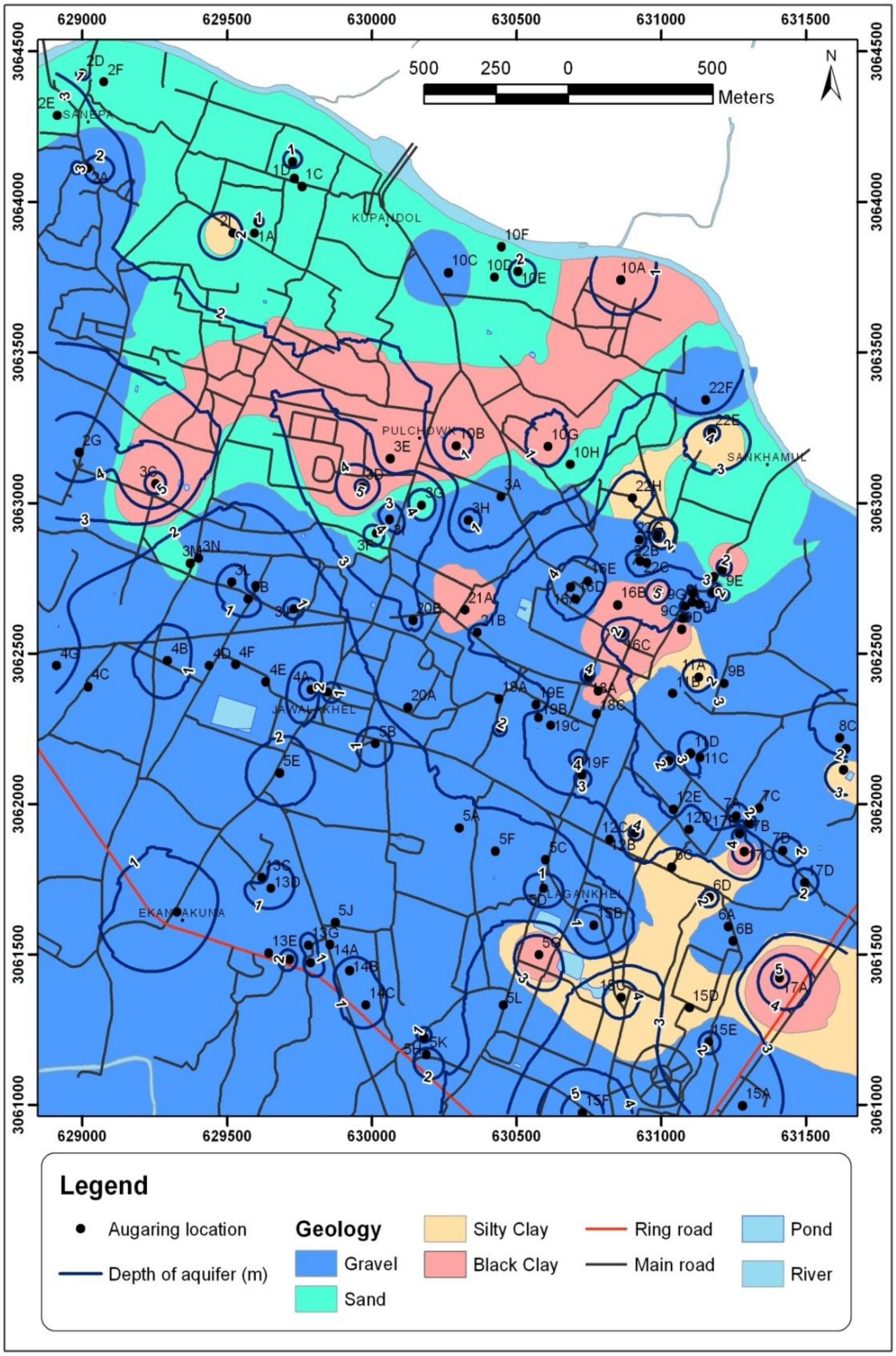

Figure 5.1: Geological map of aquifer zone and augering Location

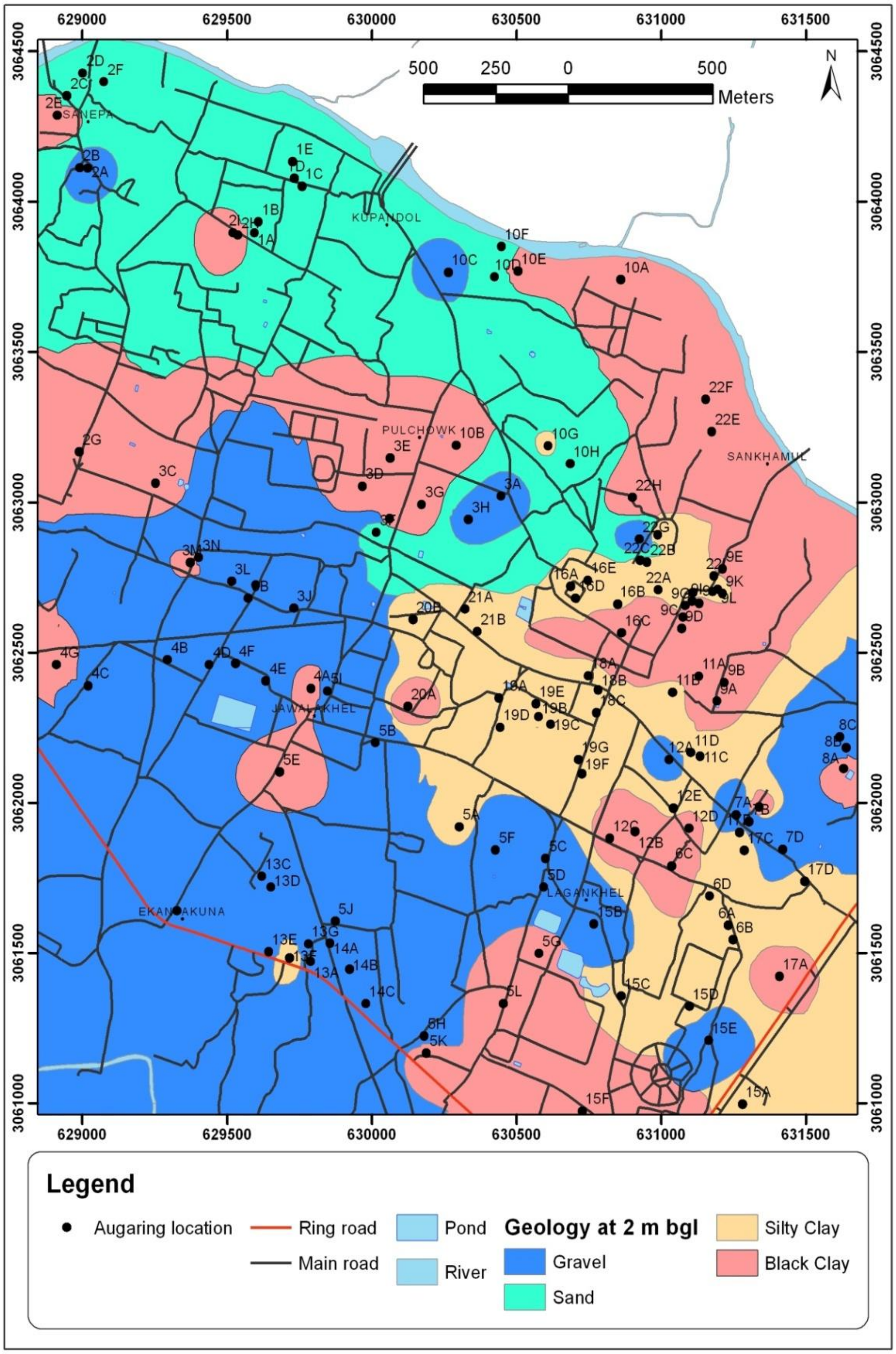

Figure 5.2: Different geological and Lithological contact and Augering Location

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1. Conclusion

- The study shows strong influence of local geology and the geomorphologic factors influencing the infiltration and recharge rates. Points located on terraces have relatively higher infiltration rates than those located on low lands due to deep water level from surface in lowlands which limits rainwater recharge.
- Thus areas around Jawalakhel, Gabahal, Kumaripati and Lagankhel in Patan show immense potential for rainwater recharge. As dug wells and shallow tube wells have higher recharge rates than the pits and infiltrometers due to their access directly to the aquifer horizons, dug wells would be good structures for recharging shallow groundwater even in places lies in Kalimati Formation.
- More than 50% of the study area is high recharge potential area which mostly covers in the Southern and Western part of the study area according to the geology, topography and infiltration rate of the region.
- The study area having mainly well graded sands except ward no. 2 Gusingal area at location point 2F; the value of CU is less than 3 i.e., 2.67 and CC is 0.03.
- The percentage of coarse material is 90% at Lagankhel area especially Patan Hospital periphery and infiltration rate is 1.2 cm/min which is relatively higher than other study area. It is concluded that Lagankhel area is more feasible than others.
- The physio-chemical parameters i.e. EC, pH, Hardness, Chloride, Magnesium, Carbonate etc. are found within the standards WHO. Almost all the values is less than WHO standard value except pH value of location 5EW2 which is 9.22.
- If the rain water harvesting systems is installed systematically, the alternative solutions for minimizing water scarcity problem, preventing abstraction deep

groundwater aquifer and opportunity for shallow groundwater aquifer through simple recharging.

6.2. Recommendation

- Groundwater Recharge and Rainwater Harvesting could reduce the scarcity problem of water in the valley in some extent, so all the residents should practice this technology and all the sectors/communities in the valley should give emphasis on this technology.
- Local community groups/clubs and NGO/INGO in the valley should initiate massive awareness campaign on the necessity and the positive factors of rainwater harvesting and recharge at household level to lessen the impact of water scarcity problem.
- Municipalities in the valley should encourage the residents to practice rainwater harvesting and groundwater recharge wherever possible. And most of open spaces such as chowks/ bahals, paved or unpaved roads should use for collecting rainwater and recharge to the groundwater by simply diverting the rainwater that falls to the recharge structures without draining out to the sewer as wastage. Most of the existing ponds within the valley should be rehabilited and can be used for collecting rainwater and recharging the groundwater.

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