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Hydrogeological Assessment in the Southern Part of Butwal Area, Rupandehi, Nepal

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Abstract

Groundwater has been utilized as the major source of water for household, irrigation and industrial purpose. The hydrogeological condition in the Terai region of the Butwal area, Rupandehi district was assessed. The subsurface lithological section and hydro-stratigraphic units of the area within the depth of 80 m were produced using secondary data from borehole lithologs. The study area i.e., quaternary deposit, comprises boulders, cobble, pebble, gravel and another alluvial (river) deposits. Thick and coarse aquifer materials (boulder and gravel) were determined at wells (DW-2,5,8 and 6), that were lying nearby rivers and foothills of Siwalik. While the proportion of finer sediments (sand and clay) was greater in the southern part of the study area. The aquifers in the study area are delineated as unconfined to confined types which are well-recharged primarily through precipitation and surface runoff in the monsoon period. The application of Duba's Method for groundwater recharge in the study area shows 44 MCM/year. Though the study area is an urban area, the physicochemical parameters like pH, TDS, DO, EC and temperature range within Nepal's Drinking Water Standard permissible limits. However, as urbanization grows, the quality and quantity may deteriorate in the future, necessitating the adoption of appropriate and sustainable management techniques to safeguard these groundwater resources..

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1. Introduction

People need water, and the largest supply of freshwater that is currently available is underground.. In many cases, ground water is not only the least expensive but the only available source. Hence, groundwater use is progressively increasing due to an increase in tube well irrigation, industrial use and municipal use, resulting in an annual increase in extraction.

The study area lies in the Butwal Sub-metropolitan city, Rupandehi District, Lumbini Zone, western Nepal of province five (Fig 1). The focus of the study is in the Southern part of Butwal, which is the Bhabar area (Quaternary deposit) lying just at the foot of Siwalik hills.

The Terai Plain, which runs along the foothills of the Himalayas, is a potential zone for groundwater resources (Rao et al. 1996). It is generally believed that the confined aquifer system in the Terai Plain is recharged from the Bhabhar zone situated at the foot of the Siwalik (Churia) hills.

Indo-Gangatic Plain (Terai) is said to be the most potential groundwater region. Terai is further divided into Northern (Bhabar), Middle and Southern Terai. Bhabar, the Northern Terai lying at the foot of Siwalik, is known as the most potential groundwater zone among all (Sharma 1974). Shah et al. (2013) have studied and published an article on the state of shallow tube well irrigation and the shallow aquifer in the Rupandehi District. They have included generally, alluvial sediment coarse and uniform in the northern part of the Terai. The major sediment transporting agent is the river in the area.

The groundwater potential is not the same everywhere as it depends upon the history of the deposition of the sediments and other related factors. Hydro-geological studies have been conducted in the study area, which is the Southern part of Butwal. This study will help to understand and divide the study area into a feasible region of groundwater, mainly deep tube wells, with the section and profiles of lithologies of the study area. The thickness of the aquifer up to 80 m depth with annual recharge of the study area is measured using Duba's method (1982). Physico-chemical parameters such as pH, Electrical Conductivity, Total Dissolved Solids, Dissolved Oxygen and temperature were measured for the groundwater quality tests.

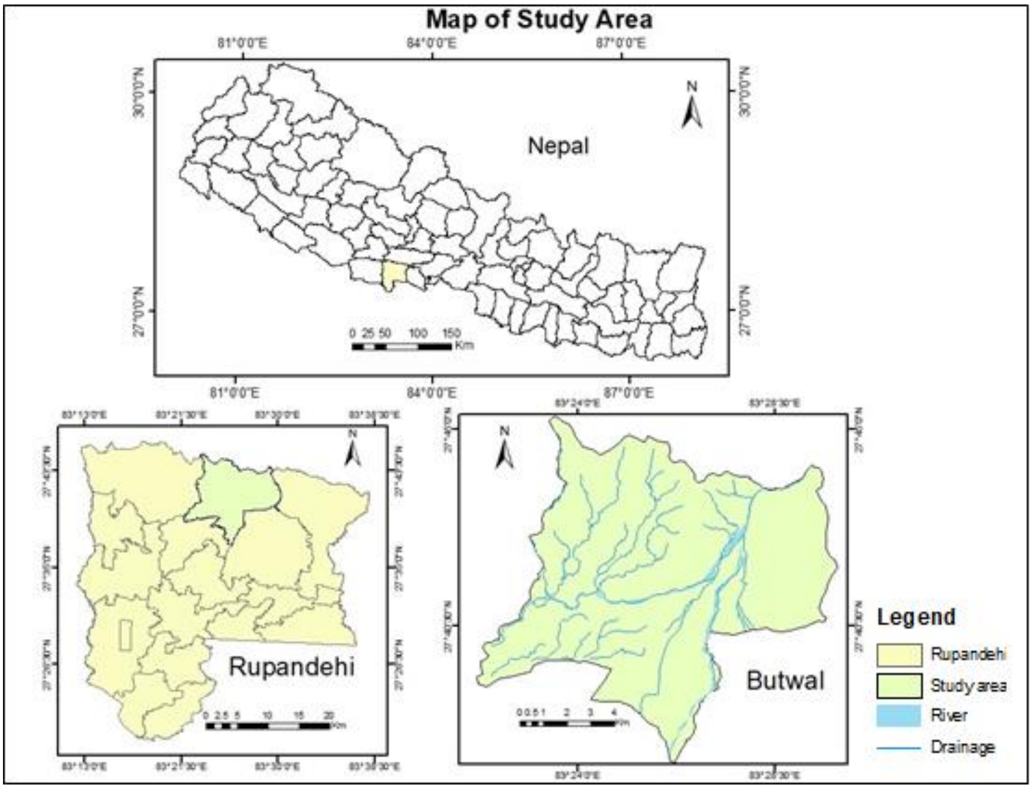

Figure 1: Location map of study area

2. Materials and Method

The research began with a literature review related to the geology, hydrogeology and climate of the study area. In this phase, topographic maps, google earth images, published and unpublished reports, literature and journals related to the present study were collected from different sources as secondary data and reviewed thoroughly. Primary data collection was done through field work. Subsurface information of the study area is worked out from the analysis of deep tube wells lithology (collected from Groundwater Irrigation Development Division, Butwal) and the information obtained in the field work. Lithologs of deep tube wells of the study area were prepared. Four cross-sections of the area were made, and then subsurface geology was interpreted. Hydro-geological conditions of the study area were studied and analyzed under different headings. Based on surface and subsurface sediment distribution, the research area's aquifer system was identified. The lithologs were able to comprehend the distribution of subsurface sediment better and the lithology data were converted to hydro-stratigraphic formations such as aquiclude (for clay), aquitard (for the mixture of clay and cuttings or sand), confined (if sandwiched by impermeable layer from both sides) and unconfined aquifer (if one side is leaky) and stratigraphic sections were taken out. An aquifer thickness map is prepared on the basis of a thickness (80m depth) of aquifer obtained from lithologs of different places in the study area. Rainfall data from 10 years (2007-2017) were analysed and the total groundwater recharge of the study area was calculated using Duba (1982) method. For the measurement of in-situ physico-chemical parameters such as pH, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO) and temperature of groundwater, Mettler Toledo was used which consists of two digital machines with three separate probes.

3. Results and Discussion

3.1 Subsurface lithology and cross-section of study area

Deep Tube Well inventory is the vital component of the study. A total of 17 deep tube wells were observed in the study area. The study area is highly porous and permeable so that it is considered as a recharge zone for the southern flat of Terai region. Subsurface materials are described in different four lithological sections with lithologs of deep drill hole (Fig 2).

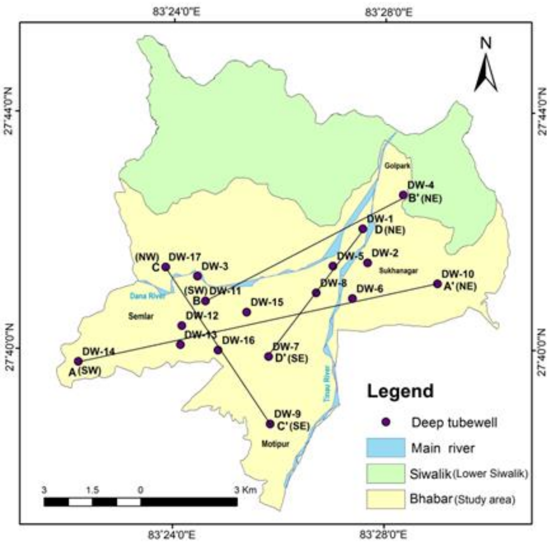

Figure 2: Map showing well location point and lithological sections line

Lithological section along A(SW)-A'(NE):

This profile is taken along Southwest to Northeast direction of the study area. The elevation of the land surface varies from 124 m to 164 m. It include Baithauliya (DW-14), Kedali (DW-13), Majuwa (DW-6), Ramnagarbyarek (DW-9) (Fig 3).

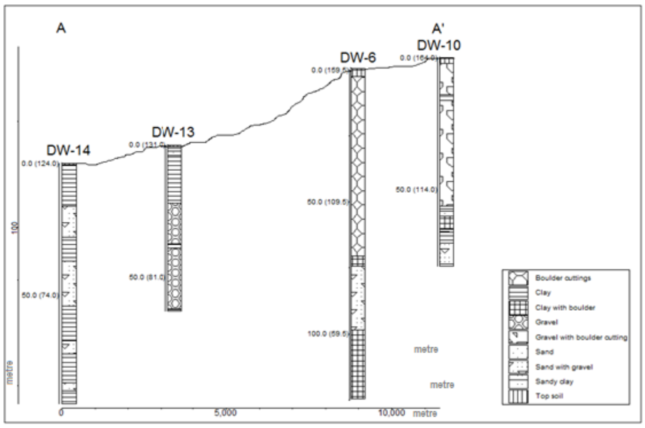

Figure 3: Lithological section along A(SW)-A'(NE)

Lithological section along B(SW)-B'(NE):

This section is also taken along southwest to northeast of the study area. The land surface elevation varies from 142 m to 225 m. It includes Ujalapur (DW-10), Abhiyanpath (DW-1) and Laxminagar (DW-4) (Fig 4). The section consists uppermost layer of top soil which is less than 2m thick in all lithologs. Laxminagar area, lying at foot of Siwalik hills, contains nearly 6m of sandy clay and Abhiyanpath consists of 30m of sandy clay and below this, thick layer of gravel and boulder is present. Whereas, lithology of Ujalapur shows layer of sand to clay at upper while repetition of gravel, boulder and clay below.

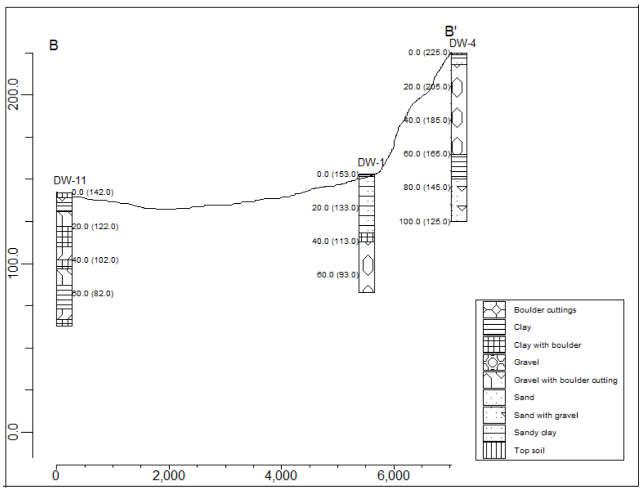

Figure 4: Lithological section along B(SW)-B'(NE)

Lithological section along C(NW)-C'(SE):

This section is taken along northwest to south direction of study area. The elevation of land surface varies from

135 m to 143 m. It includes Tamnagar (DW-17), Binayakpur (DW-16) and Pokharabari (DW-9) (Fig 5). This section shows sediment distribution clay, sandy clay, clay with gravel, sand, gravel and boulder cuttings. All the litholog shows thin layer of clay, also mixed with some sand or boulder at upper part. In Tamnagar area, thick bed of gravel lies below, and in Binayakpur and Pokharabari, sand and gravel lie below.

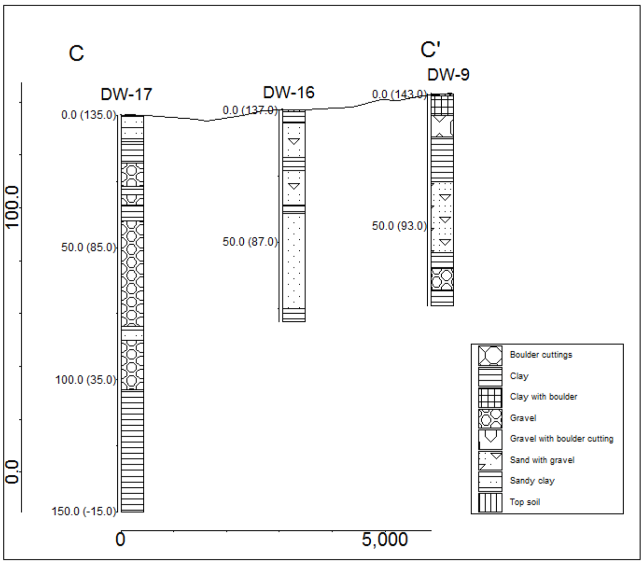

Figure 5: Lithological section along C(NW)-C'(SE)

Lithological section along D(NE)-D'(SE):

This section is taken along the northeast to south direction of the study area. The elevation of the land surface varies from 140 m to 164 m. It includes Abhiyanpath (DW-1), Majhgaun (DW-5), Naharpur (DW-8) and Bhudkaiya (DW-7) (Fig 6). This section shows sediment distribution from clay, and sandy clay to sand, gravel, and boulder. All the litholog shows a thin layer of clay at the upper part whereas thick bed of sandy clay at DW-1 at the upper part. DW-5 and DW-8 can be correlated as they consist of a thick bed of boulder cuttings and also lie nearby the Tinau river. In all areas thick bed of boulder cuttings and gravel lies at the below part.

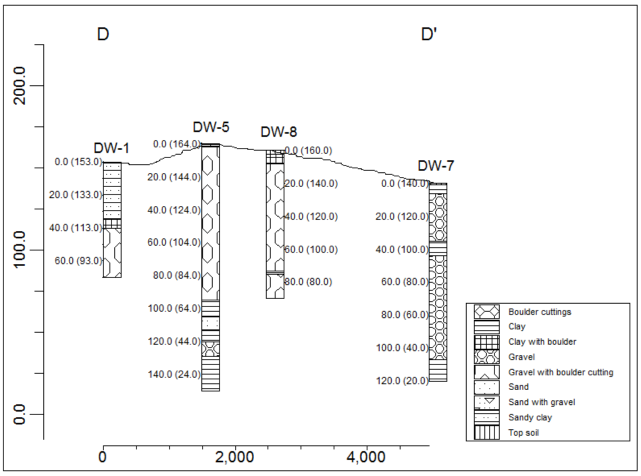

Figure 6: Lithological section along D(NE)-D'(SE)

3.2 Hydrogeological formations

Through the lithology obtained from lithologs of deep tube well, a stratigraphic section modeled map was prepared which are also known as hydrogeological formations. In stratigraphy, the sandy clay, clay with boulder was taken as aquitard, clay as aquiclude, sand, gravel and boulder as aquifer system. Based on lithologs and their lithology, stratigraphic formation was separated and section was drawn. The collected lithologs, show that the area consists of large aquifer material, coarse sediments of sand to gravel, boulder. The topmost layer is topsoil. Below the topsoil there occurred, clay and sand and gravel in the form of alternating bands. Unconfined aquifer and Confined aquifer systems are determined (Fig 7). Thick Unconfined aquifers are found at Abhiyanpath, Devinagar, Laxminagar, Majhgaun, Majuwa (Devshree), Naharpur and Tamnagar area. At Dhahawa, Pokharabari, Binayakpur, Bhudkaiya, Kedali, and Ramnagar Byarek area, the clay layers are found at thick different depths, which make the underlying aquifer confined. Fence Diagram was prepared. Hydrogeological cross-sections can be displayed in a network to form a fence diagram shown in Fig 8. In the Fence diagram, confined and unconfined aquifer with aquiclude and aquitard is represented.

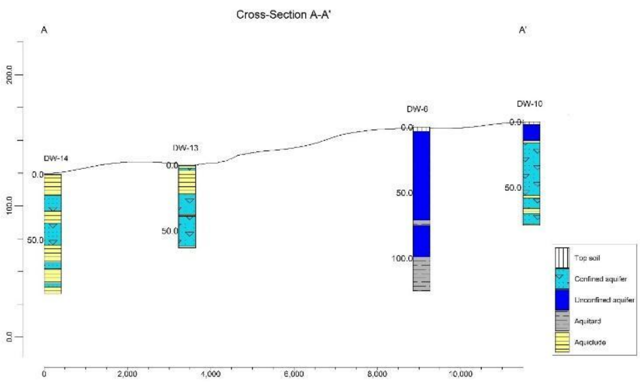

Figure 7: Hydro-Stratigraphic section along A(SW)-A'(NE)

3.3 Thickness of aquifer

A thickness map representing the Aquifer of the study area is prepared with depths up to 80 m. The thickness map is a two-dimensional color flood that depicts the areal distribution of the varying aquifer thickness over the study area. This is prepared on the basis of lithologs of the drilling. The Aquifer Thickness map (Fig 9) shows the maximum thickness of aquifer (above 50m) lies in Laxminagar, Majhagaun, Majuwa, Motipur, Mainapur, Naharpur, Ramnagar-byarek, Belbhariya, Binayakpur, Tamnagar and Devinagar area (Table 1). Thicker aquifer material is found in the wells (DW-2, 5, 8 and 6) lying nearby the river. Thick aquifer sediments are delineated at the wells nearby the river and the foothill of Siwalik whereas the aquifer unit thickness gradually decreases at the wells (DW-4, 9, and 13) towards the southern part of the study area.

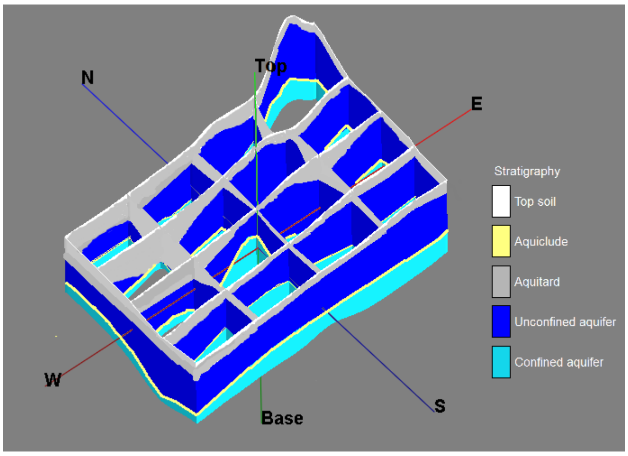

Figure 8: Fence diagram showing stratigraphic unit

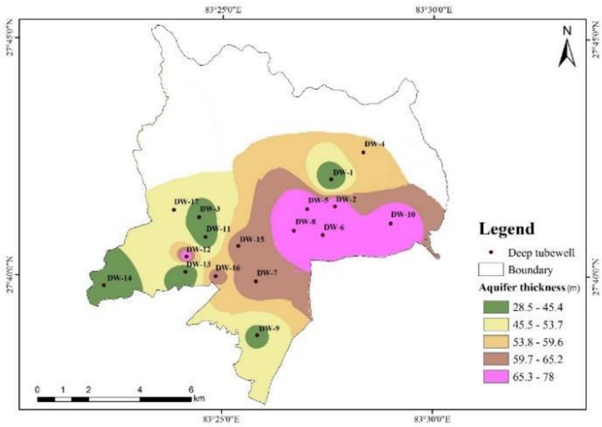

Figure 9: Aquifer thickness map of well depth up to 80m

Table 1: Thickness of Aquifer up to 80 m depth of different location points

S.No.	Location	Thickness (m)
1	Dhawa (DW-3)	37
2	Laxminagar (DW-4)	58
3	Majhagaun (DW-5)	78
4	Majuwa, devshree (DW-6)	73
5	Motipur-2, Bhudkaiya(DW-7)	65
6	Naharpur (DW-8)	70
7	Pokharabari,Motipur (DW-9)	43
8	Ramnagar byarek (DW-10)	68
9	Ujalapur (DW-11)	36
10	Mainapur (DW-12)	50
11	Kedali (DW-13)	28.25
12	Baithauliya (DW-6)	34
13	Belbhariya (DW-15)	65
14	Binayakpur (DW-16)	62
15	Tamnagar (DW-17)	53
16	Abhiyanpath (DW-1)	30
17	Devinagar (DW-2)	71

3.4 Groundwater recharge

The coarser sediments of the Bhabar Zone are either colluvium (along the foothill) or alluvium, which was deposited by rivers flowing southward from the mountainous region. The Bhabar Zone widens around major rivers and narrows in the inter-stream area. There is active recharge to the aquifer via highly permeable superficial alluvium. The recharge input is direct from rainfall and riverbed infiltration. The study area is the Southern part of Butwal which is the Bhabar zone. Duba (1982) estimated 31% of the rain that falls on Bhabar would percolate to the aquifer. Rainfall data from 10 years (2007-2017) is given in table 2. The calculation of Total Groundwater Recharge in the study area by Duba's Estimation Method is given below:

Recharge in m^3/ year = Average Annual rainfall in meters × area of recharge in km^2 × % of rainfall to aquifer =58.7 km^2 × 2413.03 mm/yr×31 = 44 MCM/yr

3.5 *Physico-chemical parameters of groundwater*

Table 3 shows the physical parameters of all wells, and Table 4 summarizes them. The most important physical parameters for assessing water quality are EC, TDS, and pH, with DO and temperature coming in second. Higher organic and inorganic solid concentrations raise EC and TDS measurements. In the study area, the Hydrogen ion concentration (pH) of the groundwater ranges from 7.2 (DW-9) to 7.78 (DW-2) with an average of 7.61. The highest pH obtained was 7.78 in Devinagar. The pH value varies slightly with all of the water samples neutral to slightly basic in nature (Tables 3 and 4) (Fig. 10).

The value of Electrical Conductivity (EC) ranges from 271 µS/cm (DW-8) to 367 µS/cm (DW-7) with an average of 329.82 µS/cm (Tables 3 and 4) (Fig. 11). The Total Dissolved Solids (TDS) value of the groundwater ranges from 148 mg/l (DW-12) to 188 mg/l (DW-9) with an average of 173.12 mg/l. In general, the TDS variation is normal in the study area (Tables 3 and 4) (Fig. 12).

The Dissolved Oxygen (DO) of the groundwater ranges from 4.5 mg/l (DW-4) to 5.2 mg/l (DW-5) with an average of 4.84 mg/l (Tables 3 and 4) (Fig. 13). In water, temperature can be both physical and chemical (SCCG, 2006). The temperature of groundwater ranges from 24.6°C (DW-4) to 26.8°C (DW-7) with an average of 26.1°C.

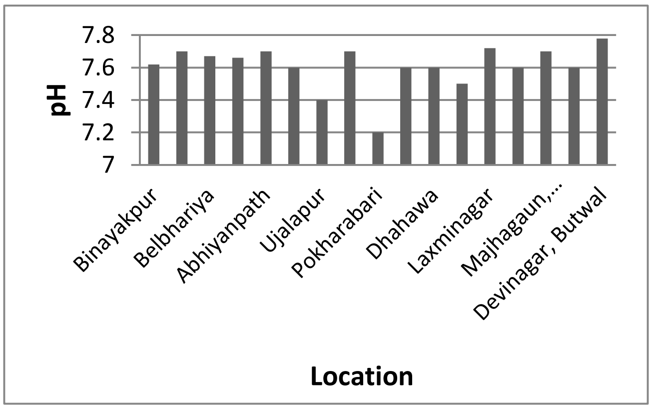

Figure 10: Graph showing the variation of hydrogen ion concentration of groundwater.

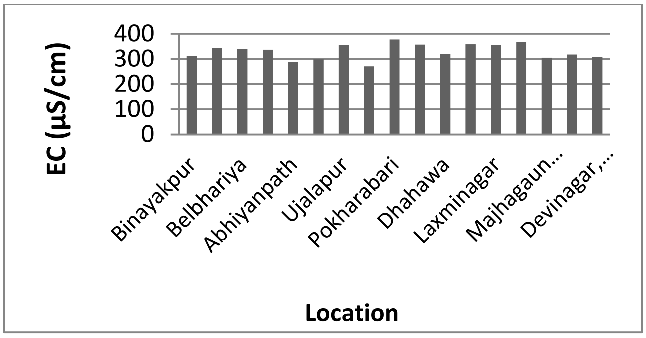

Figure 11: Graph showing variation of electric conductivity of groundwater

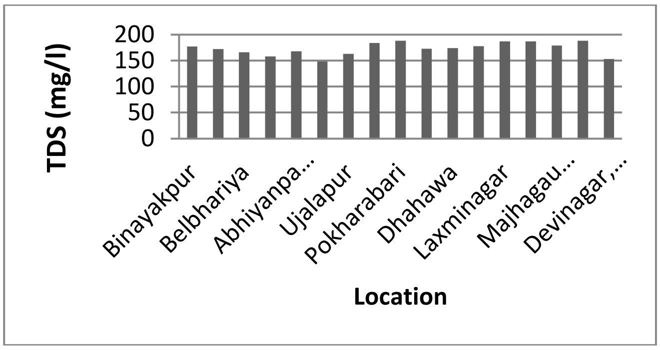

Figure 12: Graph showing the variation of TDS of groundwater

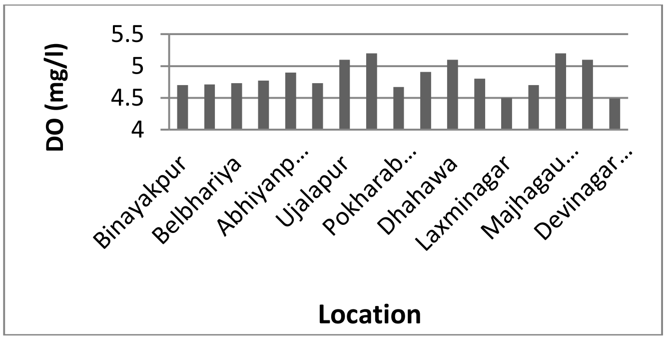

Figure 13: Graph showing variation of DO of groundwater

3.6 *Discussions*

The water supply demand of the Butwal area is fulfilled by the groundwater, recharged by precipitation and the Tinau river and its tributaries. As previous work by Sharma (1974), from the lithological section also, it is found that the main lithology is layers of gravel, pebbles, cobbles and boulders. The thin clay layers were encountered at different depths. In the Northern part of the study area, the thickness of coarser materials like boulders, and gravel is higher and toward the Southern part of the study area, the thickness of coarser material slightly decreases with the increase of fine materials like clay and sand. The lithological sections show that the thicker-coarser aquifer materials clusters in the Laxminagar (DW-4), Devinagar (DW-2), Majhgaun (DW-5), Majuwa (DW-6), and Naharpur area (DW-8), which are lying nearby to the Tinau-Dana river course. In this area, the presence of coarser material from the top with less confining material shows the potential groundwater recharge zone. And the increasing number of finer materials like clay and sand in Pokharabari, Kedali, Baithauliya and Binayakpur, which lies towards the south of the study area, shows potential for groundwater draft/wells. A similar result was published by Rao et al. (1996). Stratigraphical sections show that confined and unconfined both aquifers are present. The fence diagram, the three-dimensional figure made it easier to understand the stratigraphic unit representing hydrogeologic formations. The Aquifer Thickness map shows the maximum thickness of aquifer lies in Laxminagar, Devinagar, Majhgaun, Majuwa, Ramnagarbyarek, Tamnagar and Naharpur areas. The estimation of potential groundwater recharge by applying Duba's Method in the study area is 44 MCM per year. However, Lerner (2002) claims that the sources and pathways for groundwater recharge in urban areas are more numerous and complex than in rural areas. Buildings, roads, and other surface infrastructure interact with man-made drainage networks to alter precipitation pathways. As a result, some direct recharge is lost, but additional recharge from storm drainage systems can occur, and large amounts of water are imported into most cities for supply, distributed through underground pipes, and collected again in sewers or septic tanks. Leaks from these pipe networks frequently provide significant recharge. Groundwater quality includes physico-chemical parameters of in-situ tests that includes measurement of pH, EC, TDS, DO, and temperature. The observed tests

Table 2: In-situ test data of groundwater of study area

S.N.	Location	Well Name	longitude	Latitude	Temperature (°C)	pH	DO (mg/l)	EC (µS/cm)	TDS (mg/l)
1	Abhiyanpath	DW-1	83.4602	27.6682	26.6	7.7	4.9	288	168
2	Devinagar, Butwal	DW-2	83.4561	27.6854	24.9	7.78	4.49	307	153
3	Dhahawa	DW-3	83.4076	27.6834	26.2	7.6	5.1	320	174
4	Laxminagar	DW-4	83.4724	27.7063	24.6	7.72	4.5	355	187
5	Majhagaun, Shrijananagar	DW-5	83.4484	27.6854	26.2	7.7	5.2	305	179
6	Majuwa, Devshree	DW-6	83.4595	27.6767	26.4	7.6	5.1	317	188
7	Bhudkaiya	DW-7	83.4288	27.6586	26.8	7.6	4.7	367	187
8	Naharpur	DW-8	83.4477	27.6811	26.4	7.7	5.2	271	184
9	Pokharabari	DW-9	83.4397	27.6508	26.6	7.2	4.67	377	188
10	Ramnagar Byarek	DW-10	83.4832	27.6814	24.8	7.5	4.8	358	178
11	Ujalapur	DW-11	83.4180	27.6725	26.2	7.4	5.1	355	163
12	Mainapur	DW-12	83.4026	27.6694	26.4	7.6	4.73	298	148
13	Kedali	DW-13	83.3922	27.6592	26.4	7.66	4.77	336	158
14	Baithauliya	DW-14	83.3700	27.6592	26.4	7.7	4.71	344	172
15	Belbhariya	DW-15	83.4230	27.6733	26.2	7.67	4.73	340	166
16	Binayakpur	DW-16	83.4143	27.6626	26.4	7.62	4.7	312	177

17	Tamnagar	DW-17	83.3975	27.6858	26.2	7.6	4.91	357	173
Average value					**26.10**	**7.61**	**4.84**	**329.82**	**173.12**
Nepal's Drinking Water Quality Standards (Permissible Limit)					_	*6.5-8.5*	_	*1500*	*1000*

Table 3: Concentration of physico-chemical parameters along with standard permissible limits

	pH	EC (µS/cm)	TDS (mg/l)	DO (mg/l)	Temperature(°C)
Minimum	7.2	271	153	4.5	24.6
Maximum	7.78	367	188	5.2	26.8
Average	7.61	329.82	172.88	4.85	26.1
NDWQS, 2005	6.5-8.5	1500	1000	-	-

data is compared with Nepal's Drinking Water Quality Standards range data, which were found within the permissible limit range. The pH value is observed within the range of 7.72 to 7.78 implying that the groundwater in the area is neutral to slightly alkaline in nature.EC increases with the number of ions in the solution and also on the type of chemical species. The EC of the study area ranges from 271 µS/cm to 367 µS/cm. The values are normal in range because there is less time for mineralization. TDS is considered as an indicator of general water quality as it directly affects the water by increasing the turbidity. In the study area, TDS ranges from 148 mg/l to 188 mg/l. Low levels of TDS can be indicative of a recharge zone (Glover et al. 2012).DO originates from the atmosphere and photosynthesis is depleted through chemical oxidation and respiration by aquatic plants and micro-organisms. DO ranges from 4.5 mg/l to 5.2 mg/l. The temperature of groundwater ranges from 24.6°C to 26. 8°C.The variation in the temperature of groundwater in the study area shows that the temperature is quite the same and slightly below the minimum at higher altitudes.

4. Conclusion

Groundwater is the primary source of water for drinking, household, irrigation, and other uses in the Terai region of the Rupandehi district's Butwal area. The hydrogeological study was carried out in the Southern part of Butwal and was focused on deep tube well lithologs, subsurface lithological sections, aquifer sediment thickness distribution, recharge from rainfall, and overall distribution of physico-chemical parameters and their quality. Altogether, seventeen deep tube wells that are present in different locations, and lithology were studied. The lithological cross-sections show that the groundwater aquifer condition of deep and shallow aquifers in the Southern part of Butwal is excellent due to the presence of thick aquifer materials and the high rate of recharge from precipitation and river. The Northern part nearby the river course at the foothill of Siwalik with coarser materials is potential for recharge and the Southern part with the presence of aquifer materials and fine confining and aquitard materials shows potential for groundwater draft. The estimation of potential groundwater recharge in the study area is 44 MCM per year. However, the study area is an urban area and estimated groundwater recharge may not be fully applied and increasing urbanization may reduce recharge in the future, appropriate and sustainable management strategies must be implemented to protect and preserve these groundwater resources.

Though the recharge area is an urban area, the water quality of the study area is comparatively good as the water is less mineralized and lies within the permissible limit range in comparison with Nepal's Drinking Water Quality Standards range. However, one-time physicochemical testing of water samples does not conclude that the water is excellent or safe to use; instead, additional water quality assessments, long-term experiments, and monitoring are required.

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Conflicts of Interest

The authors report no conflicts of interest for this work.

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