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Spatial variability of shallow groundwater level in the Northern Kathmandu Valley

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ABSTRACT

Groundwater is the water which is present in pore spaces and in the fractures of the geological materials beneath earth surface. Water is incompressible substance and presence of small amount of water in geological material modifies the behavior of geological material under stresses. Determination of engineering behavior of the geological material is almost impossible skipping the role of water. The objective of this study was to map and evaluate shallow groundwater level of the northern Kathmandu Valley covering main rivers such as the Bagmati River, Bishnumati River, Dhobi Khola and the Manahara Khola. These rivers flow from the North to the South across the sand rich sediment zone. Static groundwater levels of 239 wells were measured from different locations of the study area in April/March 2017 (Dry Season) and in August 2017 (Wet Season). Shallow groundwater level was measured from soil surface to water level using well water depth logger (Qin and Li, 1998). The result showed that groundwater level ranged from 0.6 m to 12.5 m in dry season and 0.1 m to 13 m in wet season. The groundwater level increased by average of 34.68% (n = 235) as compared to that in dry season. Increase in the groundwater level suggests recharge of groundwater in wet season of the study area. The flow pattern of groundwater levels from the study shows flow of shallow groundwater towards the major rivers of that particular river watershed. As a consequence, seepage flow and piping erosion is likely along the riverbank slopes. Increase in recharge of groundwater during wet season exhibits that the northern region of the Kathmandu Valley is potential for groundwater recharge and can be used to manage water for the dry period.

Keywords: Shallow wells, Northern Kathmandu Valley, Dry season, Wet season, Water level

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INTRODUCTION

Shallow groundwater generally refers to the groundwater which is found below ground surface up to depth of 15m. This water is present in the pore spaces of the geological materials or on the fractures of rocks. The major sources of water in ancient period in Kathmandu valley used to be stone spouts, dug wells and the water direct from the river and ponds. But with the increasing population, urbanization such sources got polluted and even lead to drying of stone spouts and wells which eventually aroused the problem of scarcity of clean and safe water. Fluctuation in water level is highly dependent on the amount of use of groundwater, surrounding landuse pattern and availability of recharge area.

Many researchers have worked on the groundwater of the Kathmandu Valley (Sharma and Singh,1966; JICA, 1990; Dixit and Upadhya, 2005). JICA (1990) conducted a research on groundwater management project of the Kathmandu Valley. Dixit and Upadhya (2005) studied the groundwater condition of the Kathmandu valley and identified the avenues for groundwater potential to meet the municipal water supply need. However, there is lack of concrete approach on the study on condition of shallow wells and change in level of groundwater level during the dry and the wet periods. There is lack of detail information about shallow wells, aquifer and hydraulic dynamics of the Kathmandu Valley. This study aims to clarify groundwater condition of the Kathmandu Valley based on two seasons primarily focusing on the change on groundwater level of 239 wells that are located in the study area. The main objective of this study was to map and evaluate the shallow groundwater level of the study area of dry (pre-monsoon) and wet (monsoon) season.

The study area lies in the northern part of the Kathmandu Valley covering the major areas of the Kathmandu District and some area of the Bhaktapur District, incorporating the major drainage system of the valleys like Bagmati River, Bishnumati River, Dhobi Khola and the Manahara Khola (Fig. 1).

METHODOLOGY

Fieldwork was carried out in the month of March/April of year 2017 for collection of data of dry season and collection of wet season was carried out on August month of the same year and altogether data of 239 wells were collected from different locations of the Northern Kathmandu Valley (Fig. 1). A water-depth logger was used to measure the static water level from the wells. The water level was measured from the ground soil surface to water level (Qin and Li, 1998). After completion of data collection, data were processed to create different maps to draw result and conclusions.

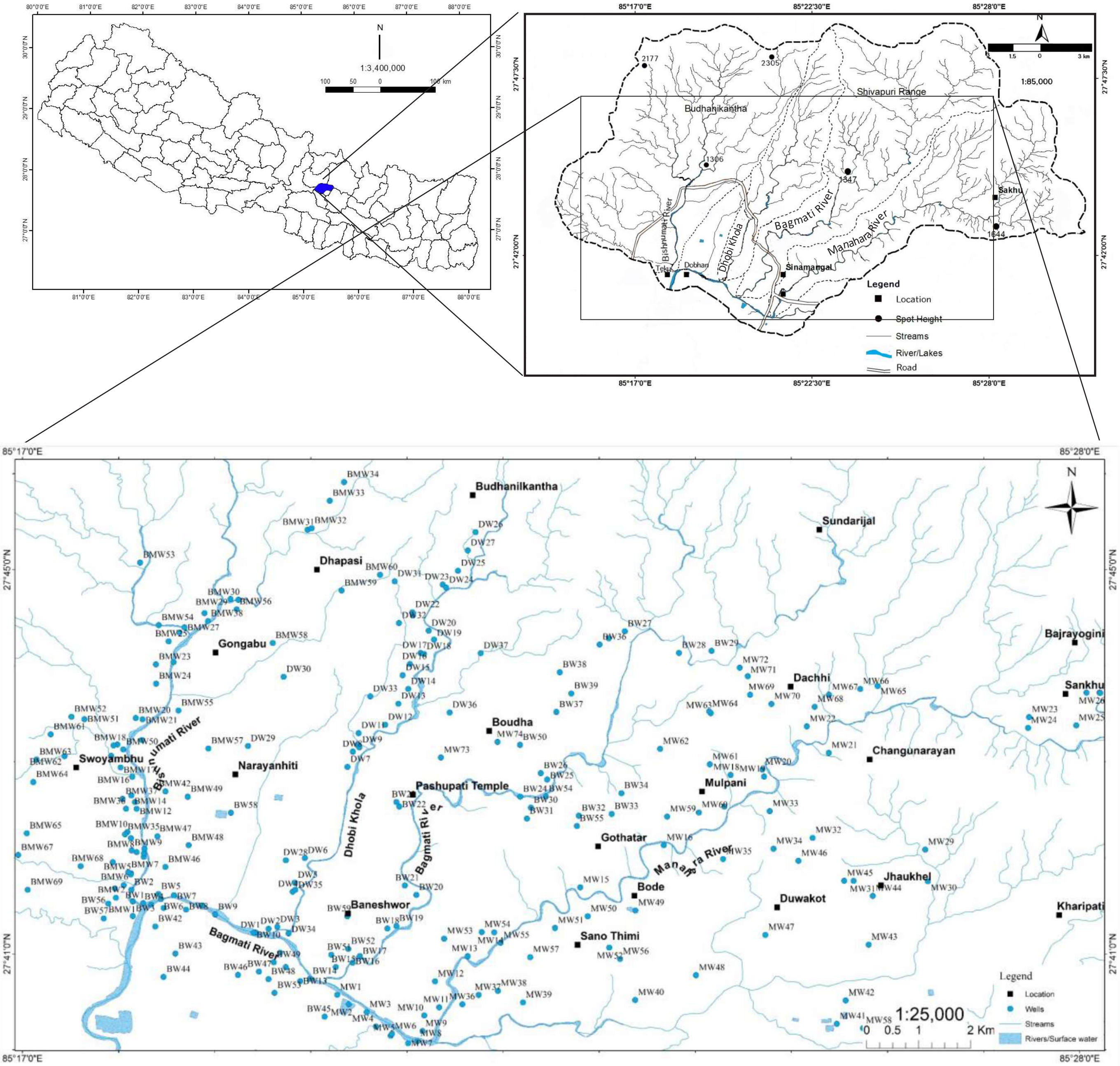

Fig. 1: Location and well distribution map of the study area

GEOLOGY OF STUDY AREA

Various studies and researches carried out in Kathmandu Valley defined their own stratigraphic units by their authors. However, this study is based on the Environmental and Engineering geological map prepared by DMG (1998) in cooperation of BGR, DOI and GMBH. Geology of study area is divided into three groups with different formations (Fig. 2). They are: (a) Quaternary Sediments, (b) Plio-Pleistocene Sediments and (c) Pre-cambrian Devonian Hard rock.

Quaternary Sediments

Quaternary Sediments includes recent unconsolidated sediments and includes following units:

Recent Alluvial Soil

This is recent deposit by flood plain and lower alluvial terraces. Sands and gravel deposits up to boulder size are found in northern part while clay, sand and fine gravel are common in southern and central part. These are high potential of groundwater with periodic change of shallow groundwater table.

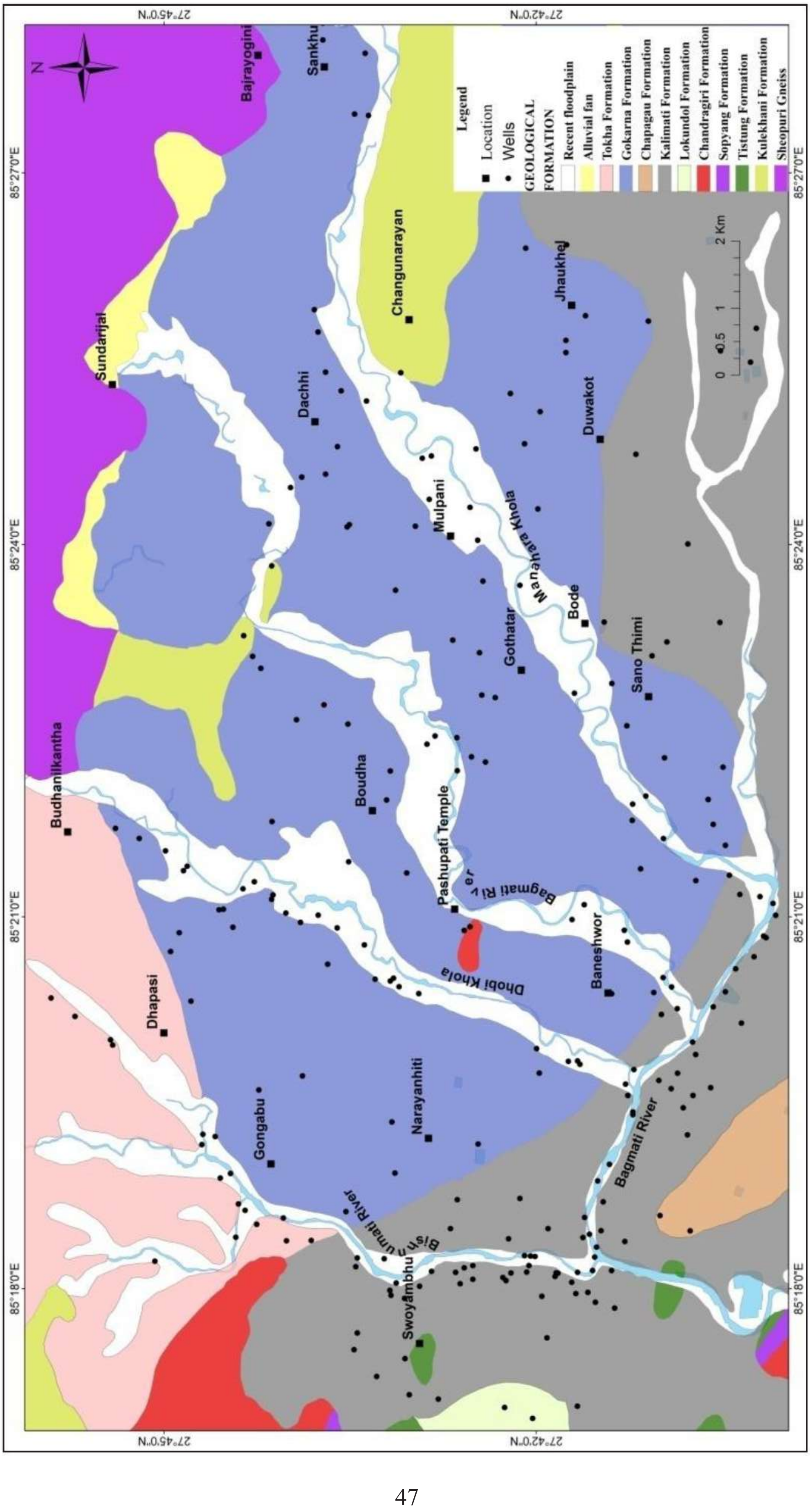

Fig. 2: Geological map of the study area with wells (After DMG, 1998).

Alluvial Fan Deposits

Gravel, sandy gravel and silt are main composition of this deposit. The thickness of deposit increases toward the centre of fan. They are highly potential for shallow groundwater, and have high infiltration rate of surface water. They may have presence of perched water.

Plio-Pleistocene Deposits

These deposits are slightly consolidated of age from Pliocene to Pleistocene. These deposits are divided into following units:

Tokha Formation

The Tokha Formation is composed of dark gray clay and brownish gray sand and poorly sorted subangular to rounded sandy gravels of thickness 200 m or more. They have moderate to high groundwater potential however groundwater table is shallow to moderately deep.

Gokarna Formation

The Gokarna Formation consists of light to brownish gray, fine laminated and poorly graded silty sand with intercalation of clay of variable thickness. The total thickness of the formation is up to 300 m. This formation has medium groundwater potential.

Chapagaon Formation

The Chapagaon Formation consists of subrounded to rounded silty sandy gravel with boulder bed, clays silt and silty sand. The total thickness of the formation is up to 110 m, and has high groundwater potential with moderately deep groundwater level.

Kalimati Formation

The Kalimati Formation consists of gray to dark silty clay and clayey silt at some places calcareous nature is also found. The thickness is up to 450 m. This formation generally has low groundwater potential and acts like an aquitard with low permeability.

Lukundol Formation

The Lukundol Formation comprises semi-consolidated sandy, clayey silt interbedded with gravel and clayey sand, peat and lignite. The total thickness is up to 80 m of this formation. It has low groundwater potential with deep groundwater level.

Precambrian to Devonian hard rock

The bedrocks found in the Kathmandu Valley range from Precambrian to Devonian age.

Chandragiri Formation

The Chandragiri Formation consists of pale bluish gray to brown, medium to thick bedded massive finely crystalline limestone with thickness of 2000 m. The limestone has good groundwater potential.

Sopyang Formation

The Sopyang Formation consists of dark, thinly bedded calcareous slate with thickness of up to 200 m. It has low groundwater potential with low to medium permeability.

Tistung Formation

The Tistung Formation comprises greenish grey to brown fine-grained phyllite and slate interbedded with metasandstone. The total thickness of this formation is up to 3000 m. This formation possesses moderate groundwater potential in metasandstone present.

Kulikhani Formation

The Kulikhani Formation consists of greenish grey biotite schist with schistose quartzite. The thickness of this formation is up to 2000 m. It has low groundwater potential with low to medium permeability.

Sheopuri Gneiss

The Sheopuri Gneiss shows different lithological characteristics. In the southern part, mica gneiss and biotite schist are common while in the northern part medium- to coarse-grained muscovite, granite with intercalation of mica gneiss and dark biotite schist are common. This formation has low to moderate groundwater potential.

RESULTS AND DISCUSSIONS

Water level measurement is the basic task in groundwater hydrogeology. Static water level of wells was measured of the study area in both dry and wet season. The data of water level of wells of two different seasons area given in the Table 1. The water level was used to find out the groundwater flow direction or flow pattern. The flow direction of groundwater is slope dependent and is necessary for quantitative analysis of recharge and discharge of the area. The water table map above mean sea level (Figs. 3 and 4) based upon depth of water level shows that general flow is towards southern part of the study area from periphery and follows the surface drainage system ultimately joining the Bagmati River. The same type of flow pattern is also observed in wet season. The maximum depth of water level was 12.5 m in Well Id BMW57 and minimum depth of water level was 0.6 m of Well Id MW25 in dry season. While in wet season maximum depth of water level was 13 m in Well Id BW61 and minimum depth of water level was 0.1 m in Well Id MW2, MW27, and DW4.

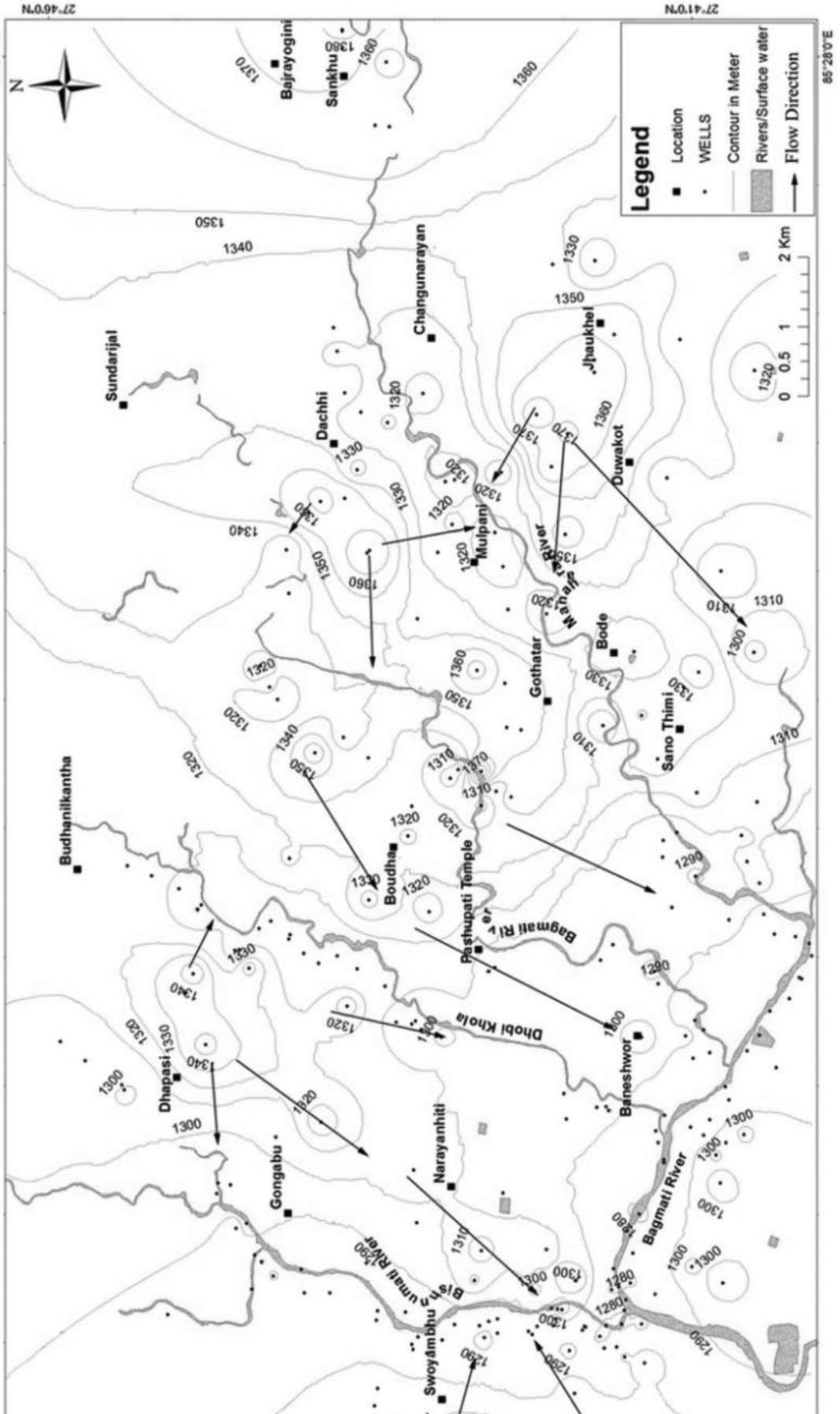

Fig. 3: Water table map and flow direction in study area in dry season

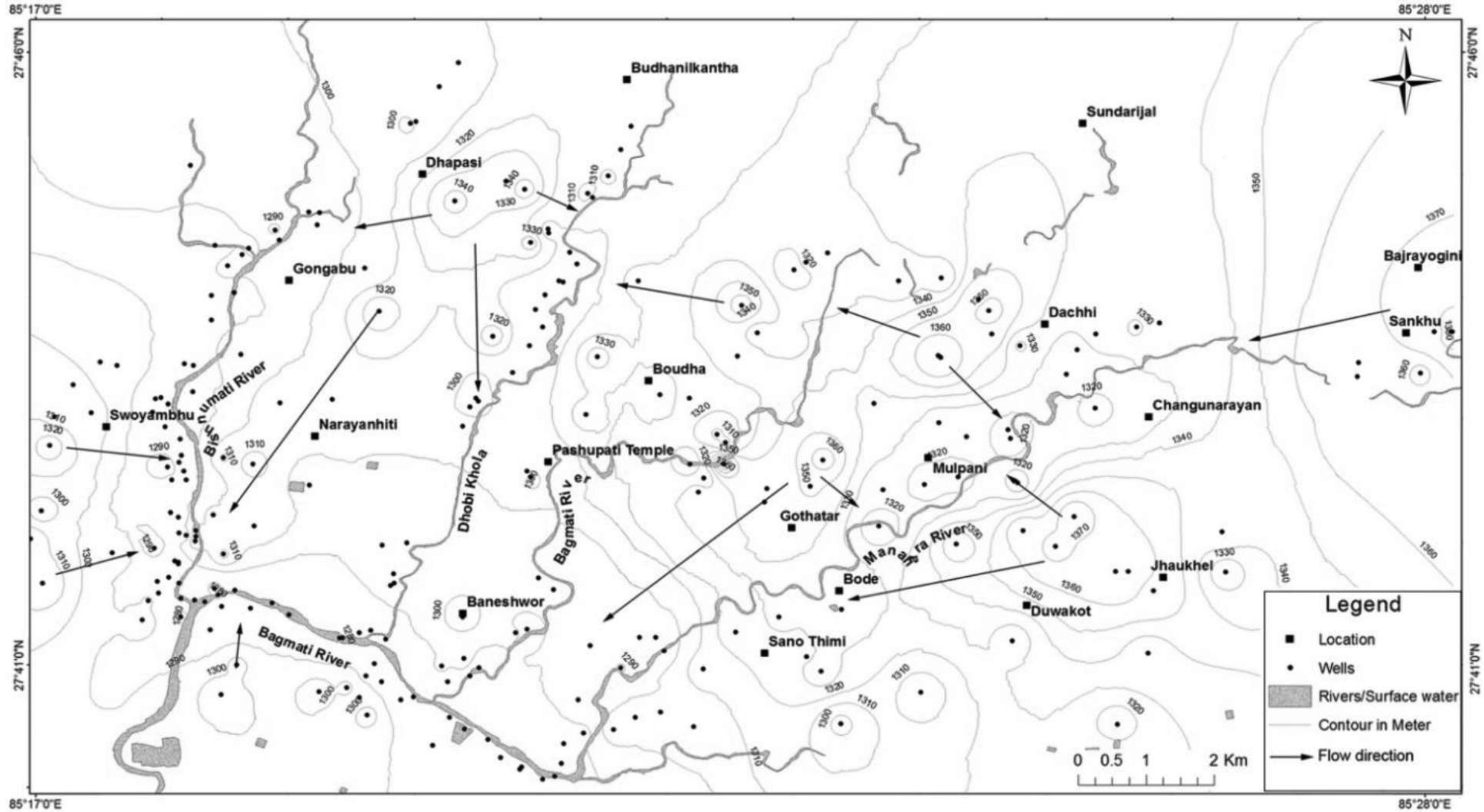

Fig. 4: Water table map and flow direction in study area in wet season

Table 1: Data of water level collected from the field

S. No	Well ID	Shallow ground water level of dry season (LD)	Shallow ground Water level of wet season (LW)	S. No	Well ID	Shallow ground water level of dry season (LD)	Shallow ground Water level of wet season (LW)	S. No	Well ID	Shallow ground water level of dry season (LD)	Shallow ground Water level of wet season (LW)
1	BW1	2.3	0.65	41	BW41	4.6	1.8	81	BMW20	4.9	0.4
2	BW2	0.6	0.7	42	BW42	6.8	5	82	BMW21	5	1.3
3	BW3	2.1	2.2	43	BW43	2.9	2.3	83	BMW22	2.25	1.6
4	BW4	1.2	1.2	44	BW44	3.9	1.2	84	BMW23	2.2	1
5	BW5	1.35	3	45	BW45	2.6	0.7	85	BMW24	6.8	2
6	BW6	1.85	1	46	BW46	1.3	0.5	86	BMW25	2.65	1.7
7	BW7	3.2	3.5	47	BW47	5.4	4.3	87	BMW26	2.7	1.7
8	BW8	2	0.9	48	BW48	1.1	0.5	88	BMW27	4.2	2.7
9	BW9	3	1.8	49	BW49	3.6	0.5	89	BMW28	3.6	1.4
10	BW10	2.6	3.4	50	BW50	3.8	2.6	90	BMW29	2.4	1
11	BW11	2.8	1	51	BW51	6.9	4	91	BMW30	1.15	0.4
12	BW12	4.15	1.6	52	BW52	2.4	1.35	92	BMW31	1.9	1.1
13	BW13	1.8	1.7	53	BW53	9	7	93	BMW32	1.55	1.1
14	BW14	2.9	1.9	54	BW54	7.05	6.4	94	BMW33	1.6	1.2
15	BW15	5.7	2.2	55	BW55	3	0.82	95	BMW34	1.4	0.4
16	BW16	7.7	2.1	56	BW56	1.3	1.1	96	BMW35	3.9	4.1
17	BW17	5.8	5.7	57	BW57	5	6	97	BMW36	6.3	5.3
18	BW18	2.5	2.5	58	BW58	3.15	2.1	98	BMW37	4	0.26
19	BW19	1	0.8	59	BW59	2.3	1.5	99	BMW38	4.2	1.3
20	BW20	4.5	1.7	60	BW60	3.34	2	100	BMW39	3.65	3.4
21	BW21	2.15	1.2	61	BW61	5.6	3	101	BMW40	NA	NA
22	BW22	2.65	2.5	62	BMW1	0.9	0.5	102	BMW41	4.8	2
23	BW23	5.8	3.3	63	BMW2	3.6	0.9	103	BMW42	3.65	3.7
24	BW24	4.75	1.8	64	BMW3	4	1.3	104	BMW43	1.6	1
25	BW25	5.1	4.6	65	BMW4	5.8	1.65	105	BMW44	4.7	2.4
26	BW26	4.1	0.6	66	BMW5	3.1	1.5	106	BMW45	4	0.75
27	BW27	4.9	1.6	67	BMW6	6.1	1.4	107	BMW46	5.1	3.8
28	BW28	3.6	2.4	68	BMW7	3.5	2.3	108	BMW47	4.5	2.5
29	BW29	1.8	1.8	69	BMW8	3.6	2.4	109	BMW48	7	3.1
30	BW30	3.1	2.3	70	BMW9	1.8	1.1	110	BMW49	2.85	2.6
31	BW31	4.4	4.8	71	BMW10	5.3	NA	111	BMW50	5.7	4.2
32	BW32	5.5	5.65	72	BMW11	3.2	1.1	112	BMW51	3	2.6
33	BW33	2.7	0.63	73	BMW12	1.8	1.3	113	BMW52	3.75	1
34	BW34	7	5	74	BMW13	3.3	2.4	114	BMW53	5	4.2
35	BW35	2.2	1.3	75	BMW14	4.8	4.2	115	BMW54	3.7	1.3
36	BW36	7	6.9	76	BMW15	NA	1.9	116	BMW55	4.5	1.5
37	BW37	2.6	0.95	77	BMW16	3	3.1	117	BMW56	3.55	1
38	BW38	7.5	7.11	78	BMW17	4.25	1.4	118	BMW57	12.5	4
39	BW39	7.2	6.75	79	BMW18	1.45	1.5	119	BMW58	1.9	0.3
40	BW40	1.5	0.9	80	BMW19	4.1	2.2	120	BMW59	3	2.6

Table 1: Data of water level collected from the field (Contd.)

S. No	Well ID	Shallow ground water level of dry season (LD)	Shallow ground Water level of wet season (LW)	S. No	Well ID	Shallow ground water level of dry season (LD)	Shallow ground Water level of wet season (LW)	S. No	Well ID	Shallow ground water level of dry season (LD)	Shallow ground Water level of wet season (LW)
121	BMW60	11.2	9.5	161	MW31	6.4	4.9	201	MW71	5.5	5.6
122	BMW61	1.6	1.1	162	MW32	3.55	0.6	202	MW72	10.7	8.9
123	BMW62	6.7	1.5	163	MW33	5.74	5.2	203	DW1	2.35	2.4
124	BMW63	9	9	164	MW34	5.6	5.1	204	DW2	2.5	2.1
125	BMW64	7.9	7.9	165	MW35	8.14	8.2	205	DW3	2.4	1.8
126	BMW65	1.6	1.6	166	MW36	3.8	2.15	206	DW4	1.6	0.1
127	BMW66	2.6	2.6	167	MW37	3.85	0.6	207	DW5	3.3	2.1
128	BMW67	2.4	2.4	168	MW38	4.36	3.85	208	DW6	2.2	1.9
129	BMW68	1.45	1.45	169	MW39	7.07	5.27	209	DW7	3.25	1.2
130	BMW69	6.1	6.1	170	MW40	5.43	5.51	210	DW8	2.55	1.6
131	MW1	5.55	5	171	MW41	5.4	2.65	211	DW9	3.3	1.1
132	MW2	1.1	0.1	172	MW42	3.27	0.6	212	DW10	5.1	0.4
133	MW3	4.8	3	173	MW43	4.34	2.7	213	DW11	2.1	2.2
134	MW4	2.85	1.7	174	MW44	9.1	8.65	214	DW12	3.3	2.5
135	MW5	2.5	1.8	175	MW45	4.65	4.4	215	DW13	1.7	0.8
136	MW6	5.7	2	176	MW46	4.62	2.34	216	DW14	2.6	2
137	MW7	1.15	1.8	177	MW47	0.65	0.13	217	DW15	2	0.9
138	MW8	3.6	1.6	178	MW48	1.05	0.2	218	DW16	1.8	1.3
139	MW9	3.1	1.9	179	MW49	3.09	2.04	219	DW17	1.7	1.25
140	MW10	5	1.1	180	MW50	6.45	5.12	220	DW18	3.8	2.5
141	MW11	4.5	3.4	181	MW51	9.25	9	221	DW19	3.7	3
142	MW12	1.8	1.2	182	MW52	5.45	5.25	222	DW20	3.2	2.5
143	MW13	3	1.75	183	MW53	4.42	4.02	223	DW21	3.3	1.7
144	MW14	4.5	4.8	184	MW54	3.83	2.98	224	DW22	3.4	2
145	MW15	3.7	NA	185	MW55	5.93	5.6	225	DW23	11.8	2.8
146	MW16	2.8	1.5	186	MW56	6.2	5.75	226	DW24	4.7	3.1
147	MW17	1.8	2	187	MW57	7.76	7.7	227	DW25	2	1.8
148	MW18	2.3	0.5	188	MW58	7.1	2.85	228	DW26	1.1	1.8
149	MW19	2.4	1.8	189	MW59	1	0.75	229	DW27	2.5	0.9
150	MW20	2	2.2	190	MW60	2.8	1.42	230	DW28	2.3	1.8
151	MW21	5	4.7	191	MW61	5.1	4.4	231	DW29	3.4	2.5
152	MW22	3.1	1.7	192	MW62	3	3.05	232	DW30	3.3	1.7
153	MW23	3.75	0.3	193	MW63	8.2	7.2	233	DW31	1.9	1.2
154	MW24	3.5	2.6	194	MW64	8.69	7.8	234	DW32	5.5	4.3
155	MW25	4.1	2.6	195	MW65	2.2	1.5	235	DW33	4.9	3.9
156	MW26	4.3	2.7	196	MW66	1.7	0.7	236	DW34	4.5	2.2
157	MW27	0.6	0.1	197	MW67	9.2	9.2	237	DW35	2.7	1.5
158	MW28	4.8	3.3	198	MW68	2.7	0.5	238	DW36	4.36	2.6
159	MW29	2.5	0.3	199	MW69	12.4	11.7	239	DW37	5.75	2
160	MW30	1.3	0.6	200	MW70	4.9	3.5				

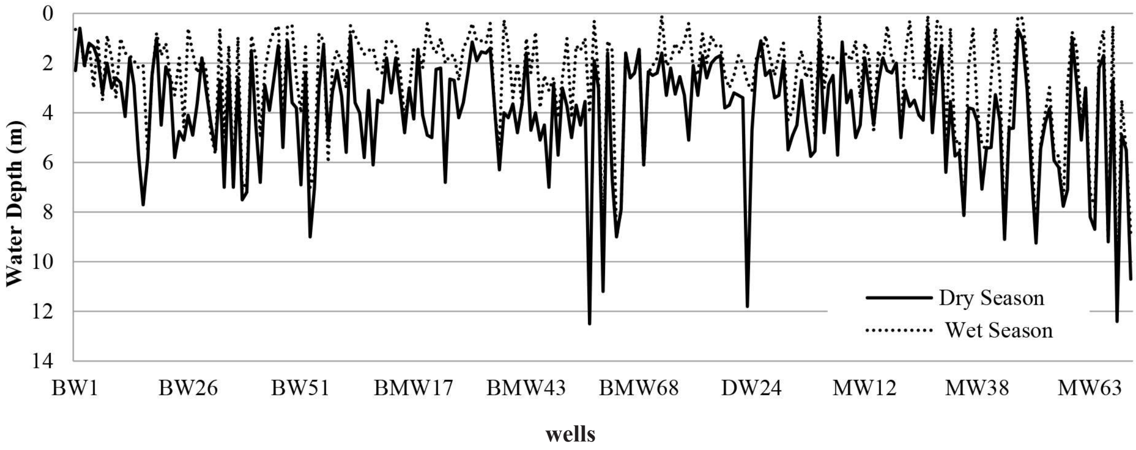

Fig. 5: Seasonal variation on water level of the study area.

Calculation: Increment percentage of water level of each well (I L) is given by:

$$IL = [(LD-LW)/LD] .100\% \quad (1)$$

Average increment of water level is obtained by:

$$ILavg = (SUM\ IL)/n \quad (2)$$

For the calculation of the increment of percentage of water level equation (1) was used where for each well the water level of wet season was deducted from dry season and divided by water level of dry season to get the increased percentage of water level in wet season. The value obtained from each well were added and divided by total number of wells to get average increment of water level. From the calculation it was found that the groundwater level increased by an average of 34.68% (n = 235) as compared to that in dry season (Fig. 5). Wells whose water level could not be obtained were not taken in the calculation.

The wells data collected from the field were overlaid in Environmental and Engineering geological map of the Kathmandu Valley (Fig. 2), 103 wells lied in Recent Flood Plain, 70 wells lied in the Gokarna Formation and 54 wells lied in the Kalimati Formation. Only two wells lied in the Chapagaon Formation, Kulikhani Formation, Lukundol Formation and the Tokha Formation. Comparing the data based on the geology, the wells which lied in the Recent Flood Plain showed increment of water level in average of 38.16%. The wells of the Kalimati Formation showed increment of water level of an average of 32.92% and the least increment of an average of 31.22% by the wells of Gokarna Formation. The reason behind high percentage of increment in Recent Flood Plain is this formation is composed of sands and gravel deposits up to boulder size along with clay, sand and fine gravel making it highly potential zone of groundwater with periodic change in groundwater level. Also wells which lies in Recent Flood Plain are near to the river corridor which easily recharge the wells increasing the water level. While the Gokarna Formation is composed of light to brownish gray, thinly laminated and poorly graded silty sand with intercalation of clay of variable thickness causing less recharge of groundwater and less increment of water level. The wells lying in the Chapagoan Formation, Kulikhani Formation, Lukundol Formation and the Tokha Formation was not taken because number of wells were very less for finding out the average result.

The flow pattern of groundwater from the study shows that the flow of shallow groundwater is towards the major rivers of the particular river watershed. Since the flow is towards the river of the particular watershed, seepage flow and piping erosion are likely along the river bank slopes as shown in some photographs (Figs. 6, 7, 8 and 9). These figures show that there are presence of seepage flow and piping erosion along the river bank slopes.

CONCLUSIONS

From the study it is concluded that the average increment in the water level of study area is 34.68% from dry season to wet season. The wells which lied in the Recent Flood Plain showed highest percentage (38.16%) of increase in water level while the wells lying in the Gokarna Formation showed least increment of water level (31.22%). The increment in the groundwater level in wet season suggests recharge of groundwater. However, the average increment percentage of water level is very low, thus it is highly recommended to find a convenient technique for maximizing the shallow groundwater recharge, such that the water can be used in systematic way in dry season. The flow pattern of the shallow groundwater level of the study area is towards the river of that particular watershed and ultimately towards the Bagmati River at the south west part

Fig. 6: Seepage water collection at right bank of the Bagmati river near Baneshwor

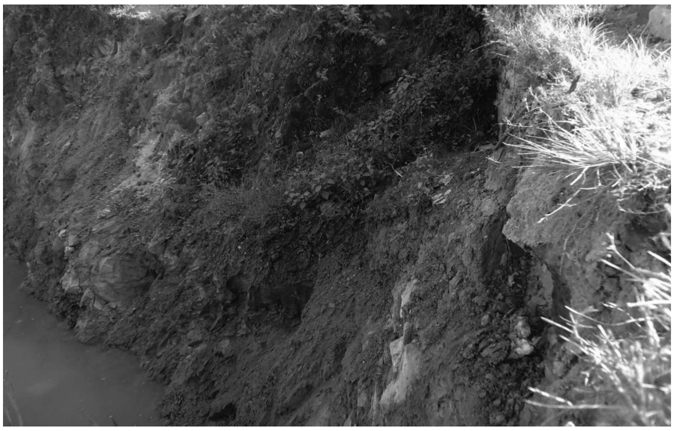

Fig. 7: Seepage water collection at right bank of the Bagmati river near Baneshwor

Fig. 8: Piping erosion observed at left bank of the Bishnumati River near Dhapasi

Fig. 9: Seepage and erosion observed at left bank of the Dhobi Khola near Budhanilkantha

of the study area. The flow of water towards river has caused the seepage and piping erosion at the river banks.

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